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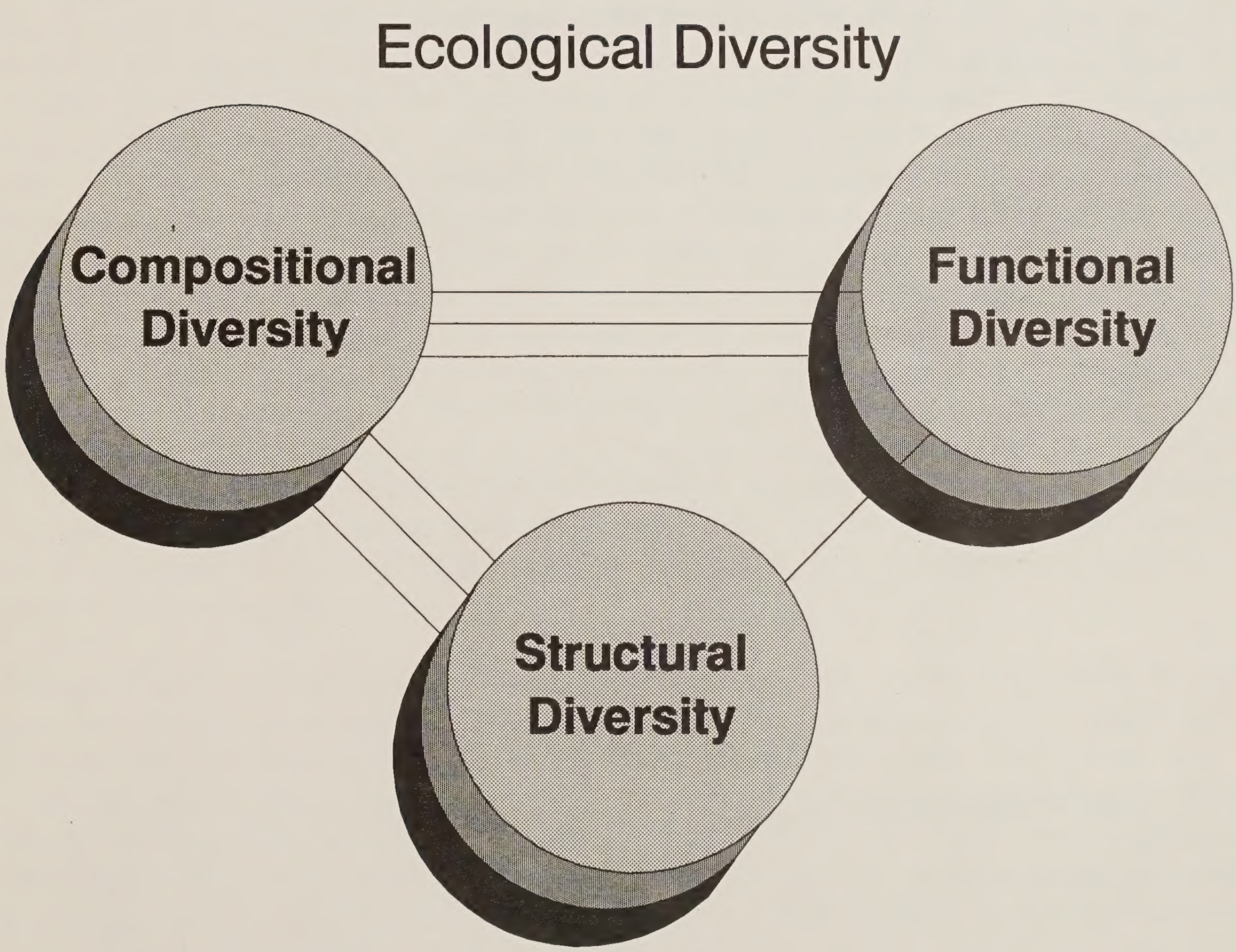
Report of the Scientific Roundtable on Biological Diversity



Report on the Scientific Roundtable on Biological Diversity
Convened by the Chequamegon and Nicolet National Forests

Submitted by:

Thomas R. Crow
Research Ecologist and Project Leader
North Central Forest Experiment Station
USDA Forest Service, Rhinelander, WI 54501

Alan Haney
Professor of Forestry
Dean, School of Natural Resources
University of Wisconsin - Stevens Point
Stevens Point, WI 54481

Donald M. Waller
Professor of Botany
University of Wisconsin - Madison
Madison, WI 53706

Submitted to:

Michael B. Hathaway
Forest Supervisor
Nicolet National Forest

Jack E. Troyer
Forest Supervisor
Chequamegon National Forest

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EXECUTIVE SUMMARY

In January of 1990, the Chief of the U.S.D.A. Forest Service directed the Regional Forester, Floyd J. Marita, and the Wisconsin National Forests to establish a "committee of scientific experts" to address biological diversity issues on these forests. The National Forest Management Act requires the National Forests to maintain and enhance the diversity of plant and animal communities as they strive to meet multiple use objectives. The Chequamegon and Nicolet National Forests initiated this process by choosing three Co-Chairs in Spring, 1992 and collaborating with them to select 19 other scientists to participate in a "Scientific Roundtable" process from 20-23 September 1992. This group was directed to assess ways in which the biological diversity of Chequamegon and Nicolet National Forest could best be protected or enhanced and was designed to facilitate consensus via open discussion of the many issues related to biodiversity. The group was chosen to obtain a broad range of expertise and observers from both Forests were present to provide background information and facilitate the process. The Forests have chosen to follow this effort with a second Roundtable addressing socio-economic aspects of managing these Forests.

The Roundtable first assessed particular risks involving biodiversity in northern Wisconsin (Chapter 3). Each risk was ranked regarding both its severity and how readily it might respond to changes in management (Table 3.1). Although some of these risks were deemed local to areas within one or both Forests, the Roundtable concluded that many biodiversity concerns were best approached on a regional or landscape scale. Risks include: habitat fragmentation; disruption of ecological processes (especially historical disturbance regimes); modification of microsites needed for regeneration and establishment by many species; pervasive modification of forest structure and composition; and genetic shifts in populations, ranging from the introduction of exotic species or alleles to the reduction or loss of native species or alleles. Fragmentation results from many causes, including the presence of roads and utility right-of-ways, the construction of dams and housing developments, the growth of trees in originally open areas, and the dispersion of timber harvests big enough to cause openings through once continuous forests. These activities also boost the amount of edge habitat, precipitating edge effects that separately threaten some elements of diversity. Populations isolated by habitat loss or fragmentation face further demographic and genetic risks, including reduced opportunities for local demographic rescue, decreased population movement along environmental gradients, and increased inbreeding and genetic drift.

Diversity may also be threatened by changes in forest composition and structure that affect ecological processes. Northern Wisconsin forests today are younger, more even-aged, and contain more early successional trees, fewer tip-up mounds, and less coarse woody debris than the mostly old-growth forests they replaced. Forests have been further modified by favoring tree species with rapid growth and high economic value and by suppressing fires that were once widespread. Because the maintenance and regeneration of many species depend on these aspects of forest structure and historical disturbance regimes, these changes have brought fewer niche and microsite opportunities for those species dependent on old or dead trees, exposed mineral soil, or conditions associated with fire.

The Roundtable next developed 23 sets of management recommendations, emphasizing how particular risks could be mitigated or eliminated and discussing how uncertainties might

be resolved via further research (Chapter 4). These recommendations include:

- conduct a regional "gap analysis" to identify community types that are under-represented in reserves or other areas managed for natural values

- protect old-growth stands and other community types identified as rare within the regional landscape

- experiment with using wide buffer zones along streams to protect water quality and provide movement corridors

- promote efforts to restore fire-dependent species, communities, and ecological processes

- use local and genetically appropriate stock for reintroduction and restoration efforts; establish genetic conservation areas for targeted tree species

- use native species and avoid exotics in revegetation programs; minimize disturbances that favor exotics

- minimize forest fragmentation to protect forest interior birds and other area sensitive or edge sensitive species; block forest management activities into larger units

- provide areas with low road density within each Forest; close or gate roads when not needed

- increase the amount of coarse woody debris left behind in harvested stands; leave live trees as well as snags

- leave some potential salvage sales unharvested

- lengthen or eliminate rotations in some management units to increase structural diversity and foster natural gap dynamics

- experiment with tree cutting techniques to assess the extent to which they create appropriate vertical and horizontal structure to foster the regeneration of understory herbs and tree seedlings

- minimize logging impacts by surveying for sensitive plants and scheduling winter harvests

- attempt to reduce deer densities in some areas of each Forest, either directly through changes in hunting practices (with the assistance of the Wisconsin DNR) or indirectly via vegetation management to locally reduce deer carrying capacity

The Roundtable also recommends that further research and monitoring are needed to more accurately detect threats to diversity and to assess how threatened elements respond to changes in resource management (Chapter 5). We propose principles to guide research and monitoring (5.2) that emphasize efficiency, statistical reliability, and timeliness. Monitoring should be

designed to include sensitive and exotic species as well as "keystone" species and population parameters. All Roundtable participants agreed that closer integration of research and monitoring efforts with management would enhance the amount of information available and the ability of forest managers to respond in timely and effective ways.

Remarkable consensus emerged on the key threats to diversity and most research and management recommendations. These efforts, however, are only the first step of an ongoing process. Many recommendations state the need for further analysis supported (where possible) by further data. The next steps include a regional gap analysis and an explicit assessment of whether area-, edge-, isolation-, and disturbance-sensitive species in the Wisconsin National Forests warrant the designation of further areas reserved from timber harvesting. More refined analyses are needed here to assess minimum area needs, the need for corridors, and the degree to which timber harvesting is compatible with maintaining species sensitive to anthropogenic disturbance. While many felt such recommendations were already supported by existing knowledge, or would be prudent under a situation of uncertainty, others felt that further research is needed before making such decisions.

The Roundtable succeeded in bringing science to bear on the complex and difficult issues surrounding biodiversity. Preparatory work provided by the staffs of the Forests combined with the expertise present to crystallize the issues and precipitate many constructive and concrete suggestions regarding forest management. We make these research and management recommendations with the hope that they will provide a useful tool for managers intent on achieving a more comprehensive and rigorous approach to ecosystem management.

Chapter 1

INTRODUCTION

1.1 Charge from the Forest Service

In response to appeals of long-range management plans for the Nicolet and Chequamegon National Forests, the Chief of the Forest Service directed these Forests to establish a "committee of scientific experts" to address biological diversity issues. This directive also was in keeping with the objective of the Forest Service to apply environmentally sensitive, socially responsive, and scientifically sound approaches to ecosystem management in implementing Forest Plans. Accordingly, Floyd J. Marita, Regional Forester, asked three prominent ecologists from Wisconsin to serve as Co-Chairs of a Scientific Roundtable which would address the subject of maintaining and enhancing biological diversity in Chequamegon and Nicolet National Forests. The Co-Chairs were: Dr. Thomas R. Crow, Research Project Leader, North Central Forest Experiment Station, Rhinelander; Dr. Alan Haney, Professor of Forestry, and Dean, College of Natural Resources, University of Wisconsin-Stevens Point; and Dr. Donald M. Waller, Professor of Botany and Environmental Studies, University of Wisconsin-Madison.

Specifically, the Regional Forester asked the Co-Chairs to:

1. Review and finalize draft goals developed by the Forests for the Roundtable.

2. Review and finalize the criteria for selecting the participants.

3. Collaborate in selecting and inviting 15-20 scientists to participate in the Roundtable.

4. Plan the Roundtable meeting focusing on the goals and expectations established by the Forests.

5. Facilitate the Roundtable deliberations to ensure that sound recommendations are reached.

Further, the Regional Forester suggested that those participating agree to:

1. Document and provide their recommendations to the Forests at the conclusion of the Roundtable, or by some early, agreed-upon date.

2. Participate in the Roundtable in such a way that the Forests can directly benefit and learn from the discussions.

3. Leave with a better understanding of the social and administrative aspects of managing forest ecosystems and offer recommendations that are sensitive to societal and managerial needs of the Forests as well as scientifically sound.

The Co-Chairs took the last admonition to mean that participants should be open-minded,

sensitive to one another's opinions, and willing to seek compromise positions.

1.2 Planning and organization by the Co-Chairs

A Roundtable Task Team was appointed by Jack Troyer, Supervisor, Chequamegon National Forest, and Mike Hathaway, Supervisor, Nicolet National Forest. Using the extensive mailing lists developed by the Forests, including all those who had commented on the Forest Plans during the review process, notice of the Roundtable was widely distributed. Suggestions for participants on the Roundtable were requested in April 1992.

Early in the discussion of Roundtable goals, it became apparent that this would be only the first of two or three Roundtables. The first Roundtable, the results of which are reported here, focuses on the biological issues of biodiversity protection and management in the Forests. Subsequent Roundtable(s) will focus on the social and economic aspects and implications. It is, therefore, important that readers recognize that this report is not intended to resolve biodiversity issues on the Forests, but rather examine the issues and offer ecological interpretations of the data available leading, where possible, to management recommendations. These recommendations will be re-examined with social and economic consideration by subsequent Roundtable(s) and by the management staff of the Forests.

In May 1992, the Co-Chairs met with the Task Team to review a list of nominees suggested for the Roundtable by Forest Service personnel, the Co-Chairs, and the public. Before identifying possible participants, the Co-Chairs compiled a list of scientific topics that they considered relevant to the Roundtable and, thus, guide the selection of scientists for the Roundtable. The list included: landscape ecology, neo-tropical migrant birds, nutrient cycling and decomposition, plant community dynamics and plant distribution, animal community dynamics and distribution, aquatic and fish ecology, invertebrate ecology, silviculture, conservation biology, soil science, paleo-ecology, forest ecology, game biology, herpetology, and population genetics.

The Co-Chairs agreed that, in addition to disciplinary expertise, those invited to participate should be highly regarded scientists with expertise in biodiversity issues. Scientists from throughout United States were considered, but preference was given to those with specific experience and knowledge of northern Wisconsin. Beyond these criteria, the Co-Chairs were also eager to identify scientists who were interested in working collegially with other Roundtable participants.

Over 100 people were suggested initially for the Roundtable. Of these, 55 qualified according to the criteria established by the Co-Chairs. During the initial review process, the Co-Chairs felt aquatic resources were under-represented in the group and added two additional names to the preliminary list. Through a systematic process of ranking and evaluating the group, 15 scientists were selected. These scientists were invited by phone to participate and a follow-up letter was mailed on 17 June at which time they were informed of the proposed process to be followed in the Roundtable. In a letter mailed on 22 June, all others who were nominated were asked to submit written comment to be reviewed by the Roundtable. In this letter, the process to be followed by the Roundtable also was indicated and the 15 scientists to be invited were identified.

Using the mailing lists of the Forests, all interested individuals were then notified of the 15 participants selected for the Roundtable and asked to comment. Letters also were sent to all relevant agencies inviting comments relating to biodiversity issues that should be considered during the Roundtable. Oral comments also were invited at a public meeting organized in Stevens Point on afternoon and evening of July 21. The Forest Supervisors, the Task Group, and the Co-Chairs were present to hear comments. Oral comments were transcribed and included with the written comments for distribution to the Roundtable participants.

Several people responded to the distribution of information on the Roundtable with comments relevant to biodiversity and/or suggestions for additional scientists who should be invited to participate. These suggestions were reviewed by the Co-Chairs and 4 additional scientists were subsequently invited to strengthen the breadth and depth of expertise represented. The 19 Roundtable participants, together with the 3 Co-Chairs, are identified in Appendix A.

The Forest Service prepared a background paper for the Roundtable. This paper, together with written and transcribed comments, pertinent published papers, and unpublished reports, were mailed to participants in late August. The Roundtable was held near Rhinelander on 20-23 September 1992.

1.3 Efforts to build consensus

The aim of the Co-Chairs and the Forest Service was to facilitate a creative and productive discussion of the issues surrounding biodiversity and resource management in Wisconsin. Smaller working groups were used to increase the efficiency of the Roundtable. Frequent oral and written reports were scheduled to provide opportunity for all Roundtable scientists to review conclusions and recommendations of each working group. These general sessions also afforded the Forest Supervisors and personnel an opportunity to gain insight into the discussions and debates among the scientists. Ground rules, established at the beginning, called for consensus where possible. Where consensus was reached, scientists were asked to state management recommendations in the context of specific objectives, attributes of diversity, and risks. Where the scientists could not reach consensus, they were asked to state specific recommendations for further study or research. The recommendations of the Roundtable are presented in detail in Chapter 4. In Chapter 2, we briefly review the scope and the approach used in the Roundtable.

Chapter 2

SCOPE AND APPROACH

2.1 Definition and importance of biodiversity

Biological diversity is a pervasive issue that has important implications for managing all natural resources. It is an issue because of concerns about the accelerating losses of species from cumulative impacts of human activities. Although the historic rate of species extinction is difficult to determine, biologists generally agree that the rate of extinction is accelerating and that this acceleration is due largely to human action. At the same time, humans are affected by this erosion of our natural resources. Concerns about species extinction are related to concerns about ecosystem health and sustainability. The ability of the biosphere to support an ever increasing number of people -- each impacting the biosphere on which they depend for substance -- is the broader, more fundamental issue that underlies discussions about biological diversity and resource management.

Forests, especially public forests, are increasingly viewed as critical areas for managing and protecting biological diversity (Probst and Crow 1991). Resource managers will be asked with greater frequency and with greater urgency to assess the impacts of their management practices on biological diversity. This is not a trivial task. Every management action affects biological diversity in some way, positively or negatively. Such requirements already apply to Forest Service planners and managers as part of the National Forest Management Act (NFMA) of 1976. Regulations resulting from NFMA reflect a desire to provide flexibility and to give professional resource managers latitude in dealing with a variety of local conditions. There is no definition of diversity within the regulations, nor are there many specific standards that must be met. Instead, NFMA states that land managers on national forests must "...provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet over-all multiple-use objectives; within the multiple-use objectives of a land management plan adopted pursuant to this section, provide, where appropriate, to the degree practicable, for steps to be taken to preserve the diversity of tree species similar to that existing in the region controlled by the plan."

It is important, however, to distinguish between a legal requirement and the practice of good scientific stewardship. Since passage of NFMA, a more comprehensive model of biological diversity has emerged. It includes both aquatic and terrestrial ecosystems, both above- and below-ground worlds, and the abiotic elements on which the biotic elements depend. In short, this model recognizes that biodiversity can only be understood from the ecosystem perspective. This comprehensive model of biodiversity is the basis for the management recommendations in this report (Figure 1).

Our definition of biodiversity comes from *Technologies to Maintain Biological Diversity* (Office of Technology Assessment 1987): "Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur." In addition to species richness, the potential impacts of resource management on genetic structure and ecosystem composition need to be considered in a comprehensive approach to

biological diversity. The spatial and temporal distribution of compositional diversity (genes, species, and ecosystems) comprise a second component, structural diversity. The interactions among compositional, structural, and functional diversity, as suggested by the linkages in Figure 1, are receiving greater attention in the scientific literature. Changes in compositional diversity and structural diversity almost certainly cause changes in ecological processes or functional diversity. Maintaining functional diversity is essential to healthy and productive ecosystems (The Keystone Center 1991, Probst and Crow 1991). Each species in a healthy, natural community contributes to nutrient retention and recycling, energy flux, gas exchange, water retention and release, soil development and maintenance, and other ecological processes. Collectively, these processes maintain the community, and allow it to adjust to perturbations, including climatic fluctuations or changes. Each species also depends on many other species for essential habitat, food, nutrition, seed dispersal, population regulation, protection from predators and parasites, and much more. Genetic diversity is the basis of all organismal diversity and provides adaptability to changing conditions that is critical for maintaining species over time and space.

It is important to recognize that each component of diversity operates at many scales, from specific sites or communities to regions. Further, migration and redistribution in the mosaic of communities at the landscape level is essential for all species. For example, species may exist for many years on a local site, but evolutionary adjustments in gene pools require genetic exchange across environmental gradients. Likewise, disturbance and successional changes can eliminate species at a local level. Even nutrient cycles have regional scales. Nitrogen budgets, for example, are determined by oxidation potentials in the soil, which are related to hydrologic fluctuations and climatic patterns. The biodiversity of any area, therefore, requires restoration and protection of ecological processes at both local and landscape levels.

Human populations and demand for natural resources have increased exponentially during the past two centuries, leading to conflicts and disruption of natural and managed systems. We have much to learn about mitigating impacts resulting from our use and modification of these communities and the resulting impacts on biodiversity in temperate regions. Much is still unknown about the extent and consequences of decreased biodiversity. Despite our deficient knowledge of the relationships, scientists generally agree that loss of biodiversity will lead inevitably to loss of sustainability. Fortunately, there are many things that can be done immediately to reduce or eliminate further erosion of biodiversity while continuing to manage our natural resources for the many uses they serve.

It is not our intent here to review the pertinent literature, but to provide enough background to establish a context for this report. Those wishing more background are referred to several books and reports on biodiversity (e.g. Cooley and Cooley 1984, Harris 1984, Office of Technology Assessment 1987, Wilson and Peter 1988, Reid and Miller 1989, Hunter 1990, Society of American Foresters 1991, Council on Environmental Quality 1993).

2.2 Model of biological diversity

The Roundtable discussion started with a conceptual model that identified 3 interrelated

components of diversity (Figure 1). The components of the model, composition, structure, and function, became the themes around which each of three working groups focused their discussion.

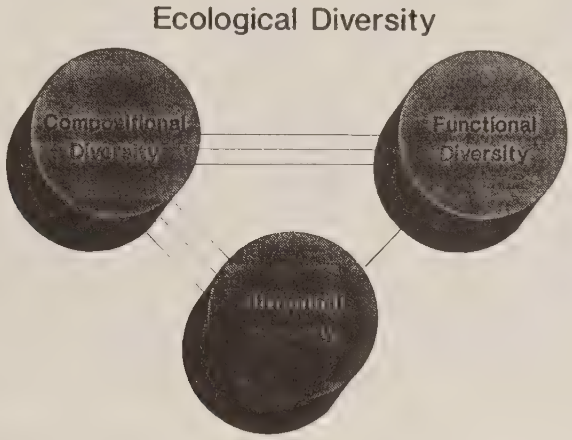

Figure 1. The interrelated elements of ecological diversity. Each element exists at multiple spatial scales (the layers in the model) from local to global.

Compositional diversity refers to the fundamental elements of diversity: the **species**, as well as the **genetic** diversity that makes up species, and the **communities** and **ecosystems** that provide their context. These elements of diversity are the most tangible and the basis for the public's general notions about diversity. Their effective protection, however, usually depends on the two other components of diversity.

Structural diversity refers to how the elements of diversity are arranged relative to each other in time and space. Thus, structural diversity includes the size, shape, and distribution of species, habitats, and communities across the landscape, and patterns of successional change. Habitat fragmentation, for example, is a perturbation that compromises structural diversity.

Functional diversity refers to the diversity of ecological **processes** that maintain and are dependent on the other components of diversity. Thus, functional diversity includes the many ecological interactions among species (competition, predation, parasitism, herbivory, mutualism, etc.) as well as ecosystem processes such as nutrient retention and cycling. Functional diversity also includes the varying tempo and intensities of natural disturbance that many species and communities require if they are to persist. Because functional diversity is less tangible than either compositional or structural diversity, it is often ignored in discussion of biological diversity. The ecological processes represented by functional diversity, however, provide the "ecological services" necesary to support all organisms, including humans.

Each component of diversity operates at multiple scales, from micro-site to regional landscapes. No component can be maintained without the other components, all operating freely at all levels.

2.3 Approach

The Co-Chairs considered it most productive to approach diversity considerations from all three directions simultaneously by breaking up the complete group into three Sub-groups, each centered around one of the components of diversity. While the division into these three Sub-groups was to some degree arbitrary, it facilitated active participation by all the scientists, leading to a full and open discussion of the many issues surrounding diversity. One Co-Chair chaired each of these Sub-groups, and, for the most part, participants were allowed to choose the Sub-group in which they wished to participate. By frequently reconvening the whole-group, the Co-Chairs allowed each of the Sub-groups to report their findings, seek consensus, and coordinate their activities. To facilitate progress on particular, more focussed issues, we also split into a number of smaller "Special Topic" Sub-groups on the second afternoon. The recommendations presented in Chapter 3 represent a synthesis from all the Sub-groups and the consensus of the group as a whole.

Each of the three main Sub-groups was asked to address the same initial set of biodiversity issues from their own perspective. To focus discussion, the Co-Chairs prepared a set of questions intended to ensure complete review of the issues and to provide recommendations that would be of value to the National Forests. These questions were:

1. What is the nature and significance of risks to biodiversity in northern Wisconsin? Questions related to this risk assessment include:

   What are the effects of current resource management practices on biodiversity?

   To what extent is diversity affected by prevailing land-use patterns?

2. How can effects of resource management on biodiversity be assessed? This question directs attention to monitoring, establishing base-line information, inventories, and research needed to support these activities. Related questions include:

   What types of data are most useful for monitoring the effects of forest management on biodiversity?

   What ecosystem processes should be monitored in the Forests to assess risks to overall ecological integrity or ecosystem health?

   Which techniques and frequencies of monitoring are most efficient and effective in providing these data?

3. What approaches are available to conserve biological diversity at multiple spatial scales?

   What are the relationships between local and regional diversity?

4. What practical recommendations can be made based on our current knowledge? Related questions include:

What additional research is needed?

How can general concepts be translated into practical recommendations?

Although discussion began with basic concepts and theories, the above questions forced the Roundtable to continually refocus on northern Wisconsin, and specifically, the Chequamegon and Nicolet National Forests. As will be apparent from the recommendations in Chapter 4, and from the preceding discussion, many biodiversity issues extend beyond the National Forest boundaries and must be addressed in this context. Where possible, the Roundtable suggested recommendations that the Forest Service could implement immediately. Where necessary, the Roundtable suggested roles the Forest Service might play in dealing with biodiversity issues across ownership boundaries, involving other decision makers, including private, state, and federal managers. Equally important, recommendations for additional study and research were made where, in the opinion of Roundtable participants, insufficient information or knowledge exists to permit management recommendations.

2.4 Guiding principles

In addition to specific recommendations for managing biological diversity, the following general principles were adopted by the Roundtable participants.

1. Maintaining the native biological diversity of the Northern Lake States should be an important goal of the Forest Service and other public land management agencies.

2. Although maintenance of biological diversity requires recognition and evaluation of many elements, some elements are still poorly recognized or understood.

3. Maintaining biodiversity depends on maintaining a suite of components, structures, and processes. Some of these are threatened by shifts in patterns of habitat aggregation and fragmentation, changes in historic disturbance regimes, and changes in the abundance and distribution of keystone species.

4. In order to fully address biodiversity, Forest Plans, to the extent possible, must address the full range of biodiversity components, including ecological processes.

5. Conflicting uses should be pursued in parallel on different land units within a landscape perspective.

2.5 Scope

The Roundtable focused on the biodiversity of the Superior Highland geographic area. The scientists recognized that diversity of this region now is different from what it was during presettlement times. Without stretching too many assumptions, they accepted the challenge of trying to suggest ways that some presettlement attributes might be restored,

while the primary goal was to develop recommendations for protecting the existing regional biodiversity.

It is unrealistic and ecologically unsound to suggest that the Nicolet and Chequamegon National Forests should alone assume responsibility for regional biodioversity. Rather, the Roundtable recommended places where the Forest Service should work with other land owners and managers, both public and private, to develop management strategies that reach across ownership boundaries. Regional biodiversity is not fully represented in the National Forests now, nor was it ever. Moreover, many regional attributes of biodiversity are better represented outside the Forests, but the Forest Service can provide leadership in developing and applying ecosystem-based (and landscape-level) management.

Coordinating biodiversity protection across the two National Forests in Wisconsin will increase opportunities to optimize attributes and management options. Improved management for biodiversity could be achieved by coordinating across all national forests in the region. The Roundtable recognized that no agency or landowner working alone can address many biodiversity issues that require large, landscape-scale approaches. The Forest Service, however, should be proactive in seeking partnerships with other landowners and managers in order to develop and address regional approaches to biodiversity protection and management. Such policies or agreements should reflect overall land use patterns in the region. For example, there are significant blocks of industrial forest lands, private preserves such as the Huron Mountain Club, Indian reservations, and utility company lands in the region, each with biodiversity management opportunities. In recognizing a need for a regional approach to biodiversity, the Roundtable was regional, although emphasis was given to Chequamegon and Nicolet National Forests.

Chapter 3

ASSESSING DIVERSITY CONCERNS

3.1 Introduction

The first mission of the Roundtable was to identify a set of diversity concerns that could be evaluated by the group in a systematic way. The morning of the first day was, therefore, devoted to identifying factors that the scientists felt represented significant immediate or potential threats to biological diversity. Each Sub-group came up with a list of factors which in the opinion of the members could threaten compositional, structural, or functional aspects of biodiversity. While each Sub-group varied somewhat in the approach taken, and in the threats identified, all three Sub-groups showed remarkable convergence in their lists of concerns. This demonstrated considerable early consensus regarding the nature and extent of processes threatening diversity in northern Wisconsin and lent impetus to the efforts that followed. This consensus was further consolidated later by debating and adopting the set of "General Principles" enunciated in Chapter 2.

Following these successful efforts to enumerate a catalog of the threats to diversity, it was then necessary to organize them into categories for further and more detailed consideration. Each Sub-group identified its own particular set of primary concerns and spent some time analyzing these issues from the point of view of composition, structure, or function. In section 3.2 below, we summarize these deliberations in a general way to provide an introduction and backdrop for the remainder of this Report. As this discussion makes clear, these components, together, act to sustain diversity. All three Sub-groups found it appropriate to organize their concerns hierarchically along a continuum of finer geographic scale, from landscapes and ecosystems, through communities and stands, to populations and individuals.

An important general goal of the Roundtable, aside from making specific management recommendations, was to assess the relative magnitude of diverse threats to diversity and the degree of scientific certainty regarding the magnitude of those threats. While most scientists at the Roundtable quickly agreed on the general nature and significance of threats to diversity, all admitted that we face considerable uncertainty regarding the full extent to which various elements of diversity are threatened, the scales at which these threats operate, and the exact mechanisms through which they operate. Consequently, protection of biodiversity should be approached through an adaptive management process. The Forests can ill afford to wait on all answers to the plethora of questions surrounding biodiversity issues. Research and management must progress together with a responsive feedback loop to incorporate new information into management decisions and policy as it becomes available. The Roundtable attempted to deal with some of the uncertainties by using a risk assessment of the biodiversity threats identified during our first session.

To assess the relative importance of various threats to diversity and the uncertainty surrounding them, it was necessary to debate each threat in turn, and assign some sort of ranking. Rather than have all three Sub-groups duplicate each other, the Function Sub-

group accepted responsibility to combine the enumerated lists of threats, categorize them, and provide an initial ranking of their severity and the level of scientific certainty surrounding them. This Sub-group also elected to rank the threats according to their judgement regarding how directly each threat might be addressed through specific changes in forest management. The Functional Sub-group then summarized its work in the form of a Table that was presented to the whole group for refinement, amendment, and adoption as another part of this Report. We describe the process further and present the Table of assessed risks in section 3.3 below. While such an exercise naturally reflects opinions of the particular scientists assembled, and is subject to change as our current understanding is supplemented by further research, Roundtable participants felt that such an explicit acknowledgement of these threats and the uncertainties surrounding them could assist the Forest Service in addressing these risks through specific management options. These assessments also provide an important foundation for understanding and appreciating the more specific recommendations that compose the next chapter.

3.2 Components of diversity

Any practical discussion of biodiversity must identify the biological entities of interest. In most cases, these targets can be placed in one of three general categories: ecosystems, populations, or gene pools. Each category, in turn, can be discussed at different geographic scales: landscapes, covering tens or hundreds of square kilometers; stands, covering a local site of relatively homogeneous habitat and its surrounding spatial context; and microhabitats, representing the fine scale structure within a single stand.

Another way or thinking about diversity has to do with scope or scale. For example, each community will have a suite of species, and each population of each species will have a number of alleles. Sexual reproduction results in continual mixing of alleles, thus maintaining the genetic diversity of the population. This diversity is important in providing each species opportunity for adaptation to environmental change. Isolated populations lose the ability to exchange genetic information and, in time, will lose fitness. Community diversity, then, not only reflects the number of species that co-exist, but also the genetic heterogeneity of each population. Communities differ one from another along environmental gradients. These may be disturbance gradients resulting in different successional communities, or they may be climatic (e.g., geographic) gradients, hydrologic gradients, or edaphic gradients. In comparing communities along these gradients, one finds both different species, as well as different alleles within overlapping species. Environmental gradients, therefore, represent another layer of diversity that extends across the landscape. Pursued far enough, environmental gradients will eventually support different types of communities with nearly, if not totally, different suites of species. For example, along a hydrologic gradient, one will find aquatic communities on one end, and xeric sand or rock outcrop communities on the other. Extending the geographic gradient across the Superior Highlands reveals elements of boreal communities on one end (Pastor and Mladenoff 1992), and tall-grass prairie and oak-hickory on the other. This landscape level diversity also must be considered. Many species will be maintained at optimal levels only when opportunities exist for gene transfer along local as well as regional gradients. This gives rise to a broader concern with connecting corridors across the landscape or,

conversely, fragmentation which affectively isolates part of the area from the rest.

Although biologists have traditionally focused on species and vegetational attributes, some of the most critical issues regarding National Forest management are at the landscape scale. These concern the size, distribution, and configuration of biological units and the linkages between them (Franklin 1988). Important issues include (1) effects of habitat fragmentation on sensitive species, (2) whether or not there is a need for diversity maintenance areas, (3) retention of coarse woody debris in managed forests, and (4) the impacts of roads on ecological integrity (Crow 1989, Probst and Crow 1991).

Structural attributes at the landscape scale include: regional forest contiguity and extent; dominance and proportion of regional and landscape ecosystems; spatial patterns of regional and landscape ecosystems including configuration, juxtaposition, patch size distributions, contrast, grain size; landscape linkages; genetic differences in races in ecotypes; age and size class distributions; and relative abundance of ecosystems.

Stand structure provides the foundation for community diversity. Vertical and horizontal components -- both above and below ground -- are critically important to stand diversity. While past management and disturbance have created a wide array of stand structures on the landscape, many components, such as associated with hardwood/conifer mixtures and old-growth forests, have been reduced in the regional landscape.

Land management actions may affect gene pools in many ways. For purposes of analysis, we identify two categories of impacts, each with different objectives and risks, thus requiring different management recommendations. The first category includes situations where genetic manipulation is a desired goal of management or where major genetic effects are a primary consequence of management. Included are situations that involve significant removal of individuals from natural or managed populations (e.g. timber harvest, hunting, fishing, or other forms of harvesting), or introduction of extraneous individuals into native habitats (genetic improvement programs, artificial regeneration after timber harvest, soil erosion stabilization plantings, wildlife reintroduction, range improvement, fish stocking, management of threatened and endangered species). The second category includes situations where genetic manipulation is not a primary management goal or objective, but where genetic effects may result from management.

Composition of genetic structure is determined by diversity of alleles and genotype frequencies among and within regions and landscapes (subspecies and racial variation), ecosystems (racial and ecotypic variation), populations ("provenance" and ecotypic variation), stands, and by diversity of alleles and genotypes within individuals. This genetic structure evolves under natural conditions to reach a balance with natural selection and environmental change. Losses in structural diversity results in imbalances of compositional diversity at all levels, resulting in greater vulnerability of species and communities to further perturbations.

As noted in Chapter 2, functional diversity refers to all those ecological processes that collectively affect the other components of diversity. For example, fire is a natural process in many communities that acts to maintain that community by removing fire-sensitive

competitors, herbivores, and diseases while providing a flush of nutrients and seed bed conditions conducive for the growth of fire-adapted species. A reduction in fire frequency or intensity may directly threaten the plant and animal species that make up fire-adapted communities. Although other assemblages of species develop, research suggests that resulting biodiversity is less than in the fire-maintained communities (Haney and Apfelbaum 1993).

Functional diversity also refers to the many ecosystem processes that link and sustain life. These include nutrient fluxes such as nitrogen fixation and the efficient cycling that often occurs between leaf litter, fungal mycorrhizae, and tree roots. Like the structural components of diversity just described, functional components of diversity "set the stage" within which plant and animal populations grow, compete, interact, and complete their life cycles. In fact, functional diversity logically includes ecological interactions among species such as competition, predation, parasitism, herbivory, and mutualism, all of which themselves depend on and interact with the larger-scale processes just described. Thus, the persistence of all species depends on functional diversity of some particular sort. Many land-use patterns can interfere with or disrupt these processes, threatening diversity in indirect ways that have often been poorly elucidated or ignored altogether.

Although all plant and animal species depend on the ecological processes that we term functional diversity, the nature of their dependence is not always obvious. In addition, because these processes are often invisible or operate over scales of time and space with which we are less familiar, functional diversity has not been studied nearly as much as compositional or structural diversity. Nevertheless, research with many species has repeatedly demonstrated the critical importance of maintaining ecological processes in sustaining biological diversity. For concreteness, we enumerate the importance of two particular functional components of diversity here. These examples serve to demonstrate how important functional components of diversity are, and how types of forest management can disrupt important ecological processes.

<u>Succession</u> - Fire, wind-storms, or logging can all initiate secondary succession. While shade-intolerant plants initially dominate a site, they tend to be replaced through time by increasingly shade-tolerant plant species that are capable of competitively suppressing the species that preceded them. Although early successional forests tend to be even-aged, later successional forests often reach a quasi-equilibrial stage at which the canopy is broken up again by individual tree-falls, allowing multiple species and age-classes to become established. As initial conditions vary and ecological conditions, including climate, continually fluctuate, these successional changes are somewhat unpredictable. Nevertheless, consistent patterns are evident in the great differences that exist between early and late successional forests, not only in species composition, but also in physical and biological attributes such as net photosynthesis, the prevalence of coarse woody debris, rates of nutrient cycling, ground flora, forest floor and soil characteristics. The frequency, type, and extent of disturbance across the landscape have correspondingly great influences on the mosaic of successional stands that result.

The nature of successional development can also have profound effects on patterns of diversity. For example, different cohorts of each species will have somewhat different

genetic composition. Moreover, it appears likely that fires were historically important in limiting the distribution and abundance of several tree pest species, including phytophagous insects, parasitic mistletoe, and perhaps bacterial and fungal disease organisms. Thus, eliminating fire or another ecological process could contribute directly to the severity of parasitic outbreaks.

Disturbance regimes - All communities tend to become occupied by plant and animal species adapted to the types, patterns, and rhythms of disturbance that occur in that community. Thus, herbs, shrubs and trees common in floodplain forests often persist by withstanding flood disturbances, or quickly colonizing floodplain areas following floods. All species, to succeed, have evolved survival strategies shaped by the type, frequency, and intensity of these natural perturbations. As a consequence, natural communities are dynamic associations constantly responding to local and regional variation in these external disturbances and the interactions among species that result from them. Historically, although disturbances were often dramatic, changes in disturbance regimes came slowly as the result of gradual shifts in climate and corresponding changes in patterns of fire, windthrow, and outbreaks of insects and diseases.

Rapid changes in disturbance regimes, or changes in the nature of disturbance in a community, tend to disrupt balances that exist among species or otherwise restrict the ecological conditions certain species require to persist. Such effects can result in a decline in diversity. Apfelbaum and Haney (1991), for example, found that eliminating fire from oak savannas in Illinois has reduced nesting passerine bird species from an estimated 30 or more to fewer than 10.

These insights regarding functional diversity suggest that the Forests should place some emphasis on maintaining (or re-establishing) historically common disturbance regimes, at least in some areas large enough to sustain populations of species dependent on such disturbances. Many of the specific threats to diversity identified in section 3.3 below reflect disruptions to historic disturbance regimes and/or corresponding patterns of community and landscape structure (e.g., habitat connectivity). For example, increases in the relative abundance and distribution of cowbirds have been traced to both increases in the amount of edge and openings due to anthropogenic disturbance of previously forested habitats as well as to increased overwintering survival.

While fire has been largely suppressed across most of northern Wisconsin, human disturbance has become widespread. With the substitution of early successional forests for the original upland mixed deciduous forest dominated by old-growth sugar maple, yellow birch, and hemlock, have come a host of changes in the character of disturbance regimes and ecological processes. For example, trees used to die individually (between large-scale disturbances), often after reaching great age. If toppled by wind, these trees would create tree-fall gaps and possibly tip-up mounds, creating conditions needed by many other species to thrive. If left standing, they would become snags providing important roosts and nesting sites for a variety of mammals, birds, insects and other animals. In either case, their wood would decay gradually in place, providing coarse woody debris that sustains a complex community of fungal and wood-boring invertebrate species, and the species that feed on them. Rotting woody material also provides important sites for seedling germination and

survival of some species. Correspondingly, land use activities that eliminate such dynamics and resources could threaten the persistence or abundance of a host of species dependent on these processes and resources.

3.3 Threats to diversity

Independent discussion by three Sub-Groups the first morning of the Roundtable led to a lengthy enumeration of the factors that can threaten biodiversity. While each Sub-Group varied in the particular threats identified, the lists reflected remarkable convergence. Lists were condensed into an organized list (Table 3.1).

To further aid the Forests in their assessment of threats, each was ranked according to three criteria:

1. the potential severity of the impacts associated with the threat,

2. the level of scientific confidence regarding this assessment, and

3. the degree or ease to which the threat might be mitigated by changes in forest management.

Our ranking under Criteria 1 and 2 serve to acknowledge explicitly the variation that exists among threats in their potential impacts on diversity and the degree of our knowledge regarding these threats. Ranks for Criterion 3 acknowledge that not all threats recognized as substantial are amenable to correction by changes in forest management; ranking, therefore, should assist the Forests in choosing which activities to pursue with the greatest likelihood for success. Although ranking the threats consumed considerable time and energy, the ranked list provides an organized foundation for the recommendations regarding management and research (Chapter 4). Indeed, deliberations regarding the level of scientific confidence led directly to many of the specific research recommendations.

3.4 Risk assessment

We are particularly concerned in the case of forest management with making appropriate decisions in the presence of ignorance. Although much is already known regarding how diversity is threatened by habitat loss, habitat fragmentation, and changes in historic disturbance regimes, most elements of biotic diversity consist of organisms that are known rather poorly (e.g., little-known species of fungi, lower plants, and soil invertebrates). We, therefore, have little knowledge of which of these species are sensitive to widespread habitat alteration or the extent to which their loss might impact other aspects of biodiversity. We also face the uncertainty expressed in Table 3.1 regarding which processes threaten well-known elements of diversity. In addition, while it is relatively straightforward to anticipate how changes in management might successful ameliorate some threats, we face further uncertainty regarding how well changes in management can address other threats.

In many cases, we know enough already to make rather specific recommendations with confidence (e.g., the need for some areas with reduced road density or traffic to restore native predators such as the wolf). In other cases, however, we do not yet have enough information to definitely claim that a given change in management will necessarily bring certain protection for some threatened element of diversity. Furthermore, many perceived threats to diversity in northern Wisconsin are based on studies done elsewhere in the region or even in other regions of the country. This has led many to recommend that more research be done locally to document the existence and extent of particular threats in this area. In still other cases, it seems likely that we do not yet even recognize threats to diversity that may ultimately prove to be substantial, and some perceived threats may prove to be less serious than now believed. For example, there is growing evidence that global warming may prove to be less of a threat that was believed only a year ago.

How should we proceed in the presence of substantial uncertainty? While it might seem conservative to simply call for further research, the Roundtable recognized that to fully demonstrate the particular mechanisms and dependencies among the elements of diversity will likely require far more time and research than is ever likely to be funded. Rather than accept paralysis, most scientists in confronting uncertainty accept two modes of action.

First, the Roundtable recommended we proceed by accepting general patterns and using these to extend results from one set of studies to predict consequences in other domains. The rankings in Table 3.1 regarding the level of scientific confidence for each threat will allow forest managers to proceed with some confidence regarding the collective expert opinion of this Roundtable.

Scientists adopt a second general approach termed "risk assessment" for addressing questions of substantial social importance in the face of uncertainty. We face similar uncertainties in make decisions regarding acid rain and potential global warming. Here, in the presence of scientifically plausible, but unproved, deleterious impacts, debates have emerged over what risks should be accepted while we postpone some options and modify others awaiting more concrete information over which interim decisions are most appropriate. Basically, decisions under such circumstances must trade-off the relative deleterious consequences of two types of error. If we change management, say by reducing the intensity or areal extent of logging because of a perceived threat when no actual threat exists, we will incur the cost of forgoing other products the forest might otherwise have yielded. Moreover, forgoing timber harvest will have environmental costs in terms of alternative materials (e.g., steel, plastics, etc.) used in lieu of timber. Alternatively, if we fail to recognize or accept a real and substantial threat because we feel that insufficient evidence exists to convince us, we may lose elements of diversity that could prove difficult or impossible to re-establish. While there exist quantitative approaches to such trade-offs, they require social and economic valuations and estimates of losses that are the focus of the second Roundtable.

While superficially similar to other global change concerns, the issues surrounding biological diversity are different in two respects. Biological systems contain numerous independently behaving components, many of which interact in subtle and indirect ways. Thus, we can expect ecological systems to be less predictable than physical systems.

Second, while we can often undo mistakes we make in designing industrial manufacturing processes that are wasteful, destructive, or threaten our health, we have no way of remedying extinction.

Table 3.1 Scientific Roundtable's assessment of threats to diversity.
In this Table, Roundtable scientists present their consensus opinion on the factors that threaten one or more elements of diversity in northern Wisconsin. Each threat is ranked on a scale of 1 to 3 (1 = high, 2 = medium, 3 = low) regarding its estimated severity, our level of confidence regarding its effects, and the degree to which that threat could be addressed via changes in forest management. Items marked with * indicate needs for further research. Items marked with + indicate threats whose resolution depends, at least in part, on cooperation with other surrounding landowners and/or agencies.

Class and nature of potential threat	Assessed severity of the impact	Level of scientific confidence regarding the impact	Estimated amenability to changes in management
1. Changes in natural disturbance regimes and landscape-level processes.			
A. **Fire suppression** - direct control of fires and indirect changes in flammability due to fragmentation of the flammable landscape have shifted the spatial and temporal scale of this disturbance and the range of seral habitats present.	1 - 3	1	1
B. **Change in gap dynamics** - the historical scales and frequencies of gaps have been altered, both by changes in forest age and composition and by changes in common disturbance regimes.			
1) Tree species	2	1	1
2) Other species	*?	3	1
C. **Shifts in biotically driven disturbance regimes** - several animals act as "keystone" species to drive the composition of the forests around them by disturbing particular species.			
1) Beaver	1	*2	1
2) Deer	1	1	*2
3) Spruce Budworm	2	2	2
2. Landscape fragmentation and aggregation			
A. **Single-species** phenomena			
1) **Edge effects**			
a) Physical (e.g., changes in humidity, light)	1 - 3	1	1
b) Biological (e.g., increased brood parasitism, deer browsing, competition from open habitat species)	1 - 3	*1 - 2	1

Class and nature of potential threat	Assessed severity of the impact	Level of scientific confidence regarding the impact	Estimated amenability to changes in management
2) Interruption of **dispersal** of native species, with consequent effects on population genetic structure and regional genetic diversity			
& 3) Increased likelihood of **extirpation** of organisms with poor dispersal (e.g., ant-dispersed forest herbs, reptiles & amphibians, soil organisms)			
a) Wolf	1	2	2
b) Amphibians and reptiles	?	3	1 - 2
c) Trees (e.g., white pines)	1	2	2
d) Herbaceous plants	1 - 3	*2	2
e) Grouse	2	2	
i. Spruce			*2
ii. Sharp-tailed			1
4) Interference with **metapopulation dynamics**, particularly for fugitive species and species with core and peripheral population structure			
a) Forest interior neotropical migratory birds	*?	3	1
b) Karner Blue Butterfly	1	2	1
5) Enhanced spread of **exotic** species			
a) Plants	?	3	2
b) Birds	3	1	2
B. **Community-level phenomena**			
1) Increased susceptibility to disturbances			
a) Windthrow	2	3	1
b) Fire susceptible species	1 - 3	1	1
2) Habitat destruction, causing a decrease in the diversity of habitat and site types represented	1 - 2	*3	1
3) Interruption of the spatial contiguity of environmental gradients, interfering with the ability of species to respond resiliently to short-term environmental changes	1 - 3	1	1
4) Disruption of communities that are patterned at large spatial scales (e.g., string bogs and other wetlands)	1	*3	1
5) Possible effects on regional climate	?	3	1
6) Edge effects (see 2.A.1)			

Class and nature of potential threat	Assessed severity of the impact	Level of scientific confidence regarding the impact	Estimated amenability to changes in management
3. Direct human effects			
A. Single-species phenomena			
1) Increased invasion by exotics (e.g., purple loosestrife, garlic mustard, game fish, zebra mussels, gypsy moth, etc.)	1 - 2	1 - 2	2 - 3
2) Large-scale plantings of exotic or genetically modified stock, with impacts on the genetic structure of native plant populations and possible impacts on the abundance of other species.	2	1	
a) Plants			1
b) Fish			+2
3) Detrimental effects due to overharvesting, poaching, collection (e.g., orchids, clubmosses, ginseng), or harassment (e.g., snakes)	*?	2	2
4) Facilitation of native species that can cross-infect other species (e.g., parasitic brainworm in moose, caribou, and elk)	1 - 2	1 - 2	2 - 3
B. Community-level phenomena			
1) Impact of logging on nutrient cycling on-site (with consequent effects on soils and possibly community composition) and water quality off-site (with effects on aquatic ommunities)			
a) Water	3	2	2
b) Land	*?	3	2
2) Impact on soil fertility or disease presense (Armillaria) of repeatedly harvesting aspen at short intervals	*1 - 2	2	1
3) Interruption of hydrological regimes in wetlands	2	2	1
4) Fisheries Management - transplanting of exotic stocks, movement of aquatic organisms between lakes on boats, indirect trophic effects.	2	1	+2
5) Impact of road development on landscape pattern and edge effects (see also 2.A., 2.B.2., 2.B.3., and 2.B.4)	1 - 3	2	2

Class and nature of potential threat	Assessed severity of the impact	Level of scientific confidence regarding the impact	Estimated amenability to changes in management
4. Direct consequences of policy structure			
A. Conflicts between management policies among public agencies	1 - 3	1	+2
B. Incomplete or inconsistent description of community types leading to inadequate efforts to conserve biological diversity		2	+1
1) Wetlands	1		
2) Uplands	2		
C. Inadequate characterization of landscape-level patterns and processes	1	*1	+1
D. Inadequate knowledge of functional characteristics of communities, ecosystems and landscapes and their impacts on biodiversity (e.g., old-growth forests, guild structure and diversity of herbs in relation to gap dynamics and soil fertility, etc.)	1	*1	1
E. Intensive aspen production on extensive portion of USFS land	1	1	1
5. Regional and global threats			
A. Global climatic change	1	2	3
B. Acid rain	2 - 3	2	3
C. Heavy metal (e.g., mercury) deposition	2 - 3	2	3
D. Toxin release (e.g., dioxins, PCB's, etc.)	1	1	3
E. Increased atmosphere CO_2	3	3	3
F. Ozone	1	1	3
G. Increased nitrogen deposition and its effects on plant communities	?	3	3
H. Movement of organisms to and from polluted areas	?	3	3

In summary, Roundtable participants generally agreed that the level of scientific understanding is currently sufficient to make the recommendations presented in Chapter 4. While substantial uncertainties and controversy persist (see Chapter 5), potential losses of diversity are serious enough to justify review and adjustment of conventional management practices across certain areas to provide for elements of biodiversity.

Chapter 4

RECOMMENDATIONS

4.1 Forest continuity and landscape structure

Objective: Maintain forest contiguity and minimize forest fragmentation to the extent possible within the Nicolet and Chequamegon National Forests.

Background: Regional and landscape forest contiguity is an important habitat requirement for species requiring large home ranges or for species requiring interior habitat conditions. Habitat fragmentation is a characteristic common to cultural landscapes. Due to their large size and ownership patterns, the Nicolet and Chequamegon National Forests can be managed to minimize fragmentation and thus perhaps provide habitat conditions that are being lost on other ownerships.

A wide variety of human activities fragment ecosystems and increase patchiness of the landscape. Fragmentation results when a large and contiguous ecosystem is converted to a network of small patches isolated from each other by interstitial areas of a different ecosystem type. Patchiness increases when the number of different ecosystem types per unit area increases. Potential changes in ecosystem composition and function resulting from changes in landscape structure are widely acknowledged in the scientific literature, but have been documented for only a few species, life forms, and landscape ecosystems. Little research has been conducted on the effects of forest fragmentation resulting from forest management.

Activities that can contribute to fragmentation include road building, logging, construction of utility corridors, dam building, human habitations, and agriculture. Whether or not these activities contribute to fragmentation depends on the species and processes being considered. For example, roads may fragment the habitat of some species, but not others. Further, the temporary edge created by forest harvesting is probably less of an effect than the abrupt, permanent edge created by urban development. In general, fragmentation results in a reduction in patch size, an increase in distance between isolated patches, and an increase in the amount of edge habitat. As a result of fragmentation, diversity may be impacted at the genetic, species, or ecosystems levels of biological organization. In addition, disturbance and climate change may put isolated natural areas at risk.

Harvesting patterns directly affect patch size, patch shape, and forest composition. Depending on the type of harvest, its timing, and subsequent treatments, landscape continuity may be reduced. Species requiring large patches, including forest species as well as open-land species, can be adversely affected. Many of the problems associated with fragmentation (e.g., edge effect, habitat destruction, interruption of dispersal) can be corrected through proper management (2.A and 2.B in Table 3.1). Maintaining continuous forest cover, as well as restoring large complexes of prairie, savanna, barren, and wetland ecosystems can provide productive areas (i.e., source areas) for species that are declining in fragmented landscapes outside the Forest boundary (e.g., neotropical migratory birds,

Karner blue butterfly, wood turtle). Within a regional context, conversion of forest lands to agricultural uses, fragmented ownership patterns, recreational and summer home development, roading, and forest harvesting have reduced the contiguity and extent of the northern forest. While loss of contiguity may be less significant within National Forest boundaries compared to other ownerships, broader regional trends affect the National Forests as well.

Recommendations:

(1) In ecosystems where ecologically significant large patches are characteristic of patterns created by historic disturbance regimes, design harvests to reduce forest fragmentation and to maintain the integrity of some large forest patches within the landscape, as well as a continuum of other patch sizes (Mladenoff et al. 1993).

(2) The possibility that the Nicolet and Chequamegon Forests serve as important sources for species requiring large, contiguous forested tracts should be examined, and the results reflected in future management.

Research Needs: Additional research is needed on the relation of forest composition and structure to biological diversity. In forested landscapes, the effect of landscape structure as measured by patch size, shape, and distribution should be studied in terms of their effects on the dispersal and production of plants and animals, and on other biotic and abiotic interactions.

4.2 Ecosystem representation

Objective: Maintain the full spectrum of ecosystems that are characteristic of northern Wisconsin. Restore representation of those ecosystems that have been lost or significantly reduced in abundance, size, and extent.

Background: Conversion of wetlands, prairies, savannas, and forests to an urban and agricultural landscape has drastically altered the representation of regional ecosystems during the last century. As a consequence, some ecosystems are under-represented in the regional landscape while others are over-represented relative to their historical context. Where ecosystems are under-represented, biological diversity may be reduced.

Recommendation: Identify ecosystems that are under-represented within protected areas in the regional landscape. If under-represented ecosystems are present within the boundaries of the National Forests, manage them to assure their continued presence and viability. In some cases, restoration of ecosystem composition, structure, and function may be necessary. The National Forests in Wisconsin should become leaders in the application of restoration ecology to their public lands.

Research Needs: A better understand of historical vegetation patterns is needed for northern Wisconsin. In addition, information is lacking about the patterns created in time and space by natural disturbances (fire, wind, disease and insect outbreaks), the interactions

of these perturbations, and the effect of disturbance on ecosystem composition, structure, and function.

4.3 Structure and composition of the regional forest

Objective: Restore a wider array of forest types, stand ages, and size classes within the regional forest.

Background: Historical cutting practices (followed by fire), conversion of forests to other land uses, and current management practices have resulted in a reduced range of tree sizes and ages in the regional forest and have simplified the structure and composition of the regional forest. For example, hemlock-hardwood and white pine forests were once regionally dominant within the Lake States. On a landscape scale, hemlock-hardwood forests were interspersed with stands in which sugar maple dominated. Basswood occurred in hardwood stands, and yellow birch was common in both stand types. The loss of conifer dominants and the decline of species such as yellow birch in second-growth forests resulted in large-scale habitat losses and changes in ecosystem processes (Mladenoff and Pastor 1993). Hemlock and white pine are among the longest living and the largest statured species in the region, producing abundant, large and persistent snags and downed logs. At the stand scale, these forests were characterized by pit and mound topography, and coarse woody debris provided sites for specialized herbaceous species and sites for regeneration of hemlock and yellow birch. Many age classes were common in the forest and the distributions of trees were clumped, providing small-scale heterogeneity. Judging from remnants of original forest, the ground flora was different in the hardwood-hemlock forest compared to the present sugar maple forest, as were the soil fauna and flora, humus types, and ecosystem processes such as decomposition and nutrient cycling.

Forests of the Lake States are still recovering from the extensive and intensive harvesting and subsequent fires that occurred during the period from 1870 to almost 1930. The "second forest" is dominated by successional species or by sugar maple, and it is more homogeneous in terms of age and size compared to previous forest. As a result, structural and compositional diversity has been lost. In addition, traditional rotation lengths applied to the current forest truncate stand development, and thus older age classes have been lost as a landscape component in many areas.

Recommendations:

(1) Attempts should be made to maintain or increase the abundance of yellow birch, white ash, and basswood in maple dominated stands through silvicultural practices such as group selection, modified shelterwood, scarification, and modified individual tree selection. Creating canopy gaps as well as eliminating advanced sugar maple regeneration will be necessary. Such treatments will be intensive and, therefore, expensive.

(2) Where remnants of old-growth hemlock exist, they should be conserved to protect the seed source. Regeneration of hemlock should be attempted along the edges of these

stands rather than in the centers of sugar maple stands.

(3) Management practices that increase the diversity of ages in stands and leave downed logs and snags may help to increase the diversity of the ground flora.

(4) In cooperation with the Wisconsin DNR, smaller deer herds should be maintained to encourage regeneration of hemlock and other species.

(5) Maintain representation of the various old-growth forests and, where appropriate, manage young forests to obtain structural and functional components characterizing mature and old-growth forests.

(6) If needed to fill gaps in age distributions, allow selected young stands to mature until structure and function develop to within the range of variation expected under a natural disturbance regime.

Research Needs: Investigate historic data on age class distributions, patch sizes, and disturbance regimes. Study the age and size structures of old-growth forests and determine whether they can be simulated through the management of younger stands. More information on regenerating hemlock is needed. Information is also needed regarding changes that occur in humus layers in hemlock stands and in hardwood stands following logging. The role of fire in the regeneration of hemlock, yellow birch, and white pine needs further investigation.

4.4 Natural disturbance regimes

Objectives: Better understand the ecological impacts of historic disturbance regimes and better emulate these impacts in forest management practices. Appreciate both differences and similarities between natural and human-made disturbance.

Background: Disturbance plays a significant role in the organization and function of all ecosystems (Mooney and Godron 1983). Along scales of time and space, disturbances range from infrequent, catastrophic, large-scale incidents to frequent, small-scale events. Wind storms, ice storms, fires, insect and disease outbreaks are all important disturbance agents in the regional forest (Runkle 1985, Frelich and Lorimer 1991). Native species are adapted to their natural disturbance regime. Most species, even those associated with old-growth communities, depend directly or indirectly on disturbance to maintain viable populations. At a landscape scale, disturbance maintains successional communities of many ages, and creates a mosaic of patch shapes and sizes that range from small gaps caused by single-tree fall or death to large patches caused by blow-downs and fires (Turner 1987).

Forest management has largely replaced natural disturbance regimes with practices that disturb the forest in ways often different from natural processes. The impacts of altered disturbance regimes on biological diversity can be significant (1.A, 1.B, and 1.C in Table 3.1). Clearcutting, for example, has a different effect on the forest and associated species than fire. Blow-downs leave more coarse woody debris on the landscape compared to

logging, and size and shape of patches is often different. In addition, fire suppression has eliminated or significantly reduced conditions necessary for initiation or maintenance of the following communities: pure or mixed stands of white birch, jack pine, red pine, white pine, and red oak on dry to dry-mesic sites and, to some extent, hemlock and yellow birch on mesic sites.

Recommendations:

(1) When feasible, use fire for establishment or maintenance of those communities that are declining as a result of fire suppression. Where the use of fire is not possible, employ mechanical means that mimic the effects of fire as closely as possible (e.g., seedbed scarification, removal of competing vegetation, etc.)

(2) Some species formerly important in fire maintained communities may have to be reintroduced by planting or seeding to re-establish the seed sources (e.g., white pine, red oak, hemlock, yellow birch).

(3) Fire should be used, as well, to regenerate some wetlands (e.g. northern white cedar, black spruce, tamarack, and most sedge and grass communities).

Research Needs: Much additional information is needed on using fire as a management tool in the Great Lakes Region. Disturbance characteristics (size, intensity, frequency and regularity, duration, seasonal time of occurrence, landscape heterogeneity) need to be studied in relation to population and life-history characteristics such as species density and dispersion, age and size structure, genetic structure, niche requirements, life span, and reproductive strategies in order to make better use of disturbance as a management tool.

4.5 Genetic diversity

Objective: The general objective is to maintain genetic diversity at all scales, including within-stand genetic diversity of representative and extreme populations, and geographic patterns of genetic diversity at the stand, ecosystem, landscape, and regional scales.

Background: Genetic diversity provides the raw material by which species evolve and adapt to changing conditions. Reductions in genetic diversity at all scales may have detrimental effects on other elements of biological diversity. The temporal and spatial ranges of genetic diversity found on areas of high genetic integrity provide an estimate of "natural genetic diversity" and provide the context for evaluating the impacts of management on genetic diversity. In the vast majority of cases, direct genetic information is not available, but patterns of diversity can be inferred from studies of related species or life-history correlates, and from knowledge of eco-physiographic zones.

Loses of genetic diversity are associated with:

(1) Decreases in among-stand genetic diversity related to population extirpation, artificial regeneration that relies on a single (or few) seed sources, monocultures, and reduced

gene flow resulting from habitat fragmentation or other physical barriers to dispersal.

(2) Changes in selection pressures related to changes in biotic and abiotic factors. Examples include changes in competition resulting from changes in composition and stocking; changes in soil, light, microclimate, or other abiotic factors; changes in disturbance regimes such as fire, insects, and pathogens.

(3) Decreases in within-stand genetic diversity resulting from decreases in effective population sizes, changes in mating systems, changes in composition of breeding individuals, or changes in temporal levels of stand heterozygosities.

(4) Gene contamination by "exotic" alleles and genotypes and novel combinations of native alleles (e.g., unusual gene frequencies, hybrids). Any project that involves planting, stocking, introducing, or breeding in which the germplasm origin is unknown runs the risk of gene contamination. Altered selection regimes in nurseries and captive propagation, and accidental introduction of exotic species also cause gene contamination.

(5) Increases in inbreeding and outbreeding depression that are related to changes in population size and age class distribution (number of adults available).

Recommendations: Coarse Filter Approach

The following guidelines are suggested if intensive management is not feasible or when genetic manipulation is not a primary management goal.

(1) Include geneticists on ID teams for planning and project implementation and in program review; coordinate with NFS Genetics Resource Program (formerly Tree Improvement Program); support genetics expertise at Regional and Planning staff levels; provide opportunities for training of resource staff in genetics.

(2) Include analyses of genetic structure and variability as part of the management of special management areas, e.g., Research Natural Areas, Genetic Conservation Areas, Special Interest Areas, Wilderness Areas. Include both central and marginal or unusual populations, and duplicate ecosystems within special management areas to capture the geographic diversity within an ecological zone and for redundancy.

(3) Genetic monitoring should be an integral part of the Forest monitoring program. This may include the monitoring of trends in Research Natural Areas and Genetic Conservation Areas, monitoring the recovery and maintenance of Threatened and Endangered species, as well as specific monitoring objectives such as comparing genetic diversity in unmanaged stands to stands being managed under diverse silvicultural methods.

Recommendations: Fine Filter Approach

In situations where genetic management is a primary goal of management, genetic

manipulation plays a large enough role that detailed genetic management guides should be written and reviewed on a case-by-case basis. These are usually high priority situations where management intensity is high. For example, in species restoration, the nature of the germplasm and its deployment should be specified taxon by taxon; in harvest of special species such as lichens and club mosses, the impacts on genetic structure should be used to develop levels of take; in timber harvest, silvicultural methods being considered should be evaluated for their effects on resulting genetic structures of stands; in fish stocking, the origins of stock should be determined.

Some situations may justify deviation from the overall management objective described above and thus may counter general recommendations that seek to avoid the risks listed above. For instance, if an extremely rare, endangered species is near extinction, general genetic conservation guidelines may not apply, since demographic stability is the urgent goal, and alterations in genetic structure may be attempted as remedial action. Similarly, breeding programs may have explicit goals to alter natural genetic structure, for instance to increase fiber production or provide populations with genetic resistance to insects or pathogens. Although these programs have specific genetic goals, this is not a license to ignore the objectives and potential risks above.

Timber Program. -- (1) Support genetically based seed-zones, seed transfer rules, and seed collection guidelines that have the objective of maintaining broad genetic architecture for all species artificially regenerated. (2) Review tree improvement and regeneration guidelines to determine how genetic diversity is being impacted. (3) Promote natural regeneration where possible, and where suitable, use native germplasm as the parent stock. (4) Evaluate silvicultural methods (including alternative silvicultural methods) for their genetic impacts. Avoid dysgenic selection and conditions that increase inbreeding (solitary breeding trees left, or isolated family clusters). (5) Encourage establishment of oak in pine plantations, and white pine and hemlock in northern hardwood stands. (6) At harvest time, replace jack pine plantations of unknown source (e.g, CCC plantations) with appropriate local stock. (7) Promote breeding programs for genetic resistance to diseases and insect damage where appropriate, but maintain a broad genetic base.

Community Restoration, Reclamation, Habitat Improvement (roadside seeding, post-fire seeding, erosion control, planting in wildlife openings). -- Promote use of appropriate germplasm, using native species and adhering to genetic guidelines regarding origin of seed (appropriate local, ecologically matched sites).

Species Reintroduction (introduction of species into former range). -- (1) Choose ecologically (genetically, if known) similar, local populations of known native germplasm as source for reintroduction. (2) Consider using mixture of germplasm from several populations to form diverse gene pool for reintroduction.

Threatened and Endangered Species Management. -- (1) Expand the inventory and monitoring of Threatened and Endangered plants and animals; implement recovery plans. (2) Emphasize population viability analyses for Threatened and Endangered species.

Toumey Nursery. -- (1) Expand the role of the Nursery beyond traditional commercial

species to include all plant species in need of regeneration and reintroduction on the Forests. (2) Promote adoption and use of genetic management processes in nurseries for new species regarding: a) seed source guidelines, b) genetic base guidelines, c) seed extraction and handling, d) propagation with appropriate control of genetic lots, e) education of Forest staff by Nursery personnel regarding genetic control.

Genetic Conservation Areas (GCAs). -- For targeted species, do genetic gap analysis and establish genetically based network of Genetic Conservation Areas using the Mixed Conifer GCAs in Central Sierra, California, and the Pacific Yew GCAs in the Pacific Northwest as models.

Research Needs: (1) Investigate the value of genetic correlates (life-history traits) for predicting genetic diversity of forest species. (2) Investigate the value of using ecological-physiographic units as predictors of geographic level gene diversity in forest species. (3) Research sampling design and protocols for genetic monitoring of different classes of plants and animals. (4) Conduct genetic studies where possible for species of high priority/concern, but resist temptation to use only biochemical or molecular techniques if the species is unknown genetically. (5) Research the genetic attributes necessary to conduct population viability analyses for target species (gene flows, effective population size, generation lengths, variation in offspring number, temporal variation in population size). (6) Conduct studies on appropriate germplasm collection (genetic base) and germplasm transfer guidelines (optional sampling sizes for diversity maintenance) for species used in restoration, reclamation, and wildlife habitat improvement. (7) Compare effects of manipulation (silvicultural methods, germplasm introduction) on genetic diversity in undisturbed populations (e.g., timber species, non-traditional harvest species [club mosses, lichens, Canada Yew], fishes, grasses, wildlife browse species...) and the effect on population stability/viability. (8) Study persistence and invasiveness of useful exotic species to identify those that could be used transiently for restoration. (9) Study persistence and viability of reintroduced populations that derive from a) mixed local gene pool, or b) limited local gene pools. (10) Research role of genetic diversity in recovery of extremely endangered populations and species. (11) Investigate possible selection effects of Nursery Culture Conditions on genetic diversity of plants being propagated. (12) Develop methods for determining genetically appropriate (= size and location) Genetic Conservation Areas. (13) Investigate effects of stocking exotic fish and exotic germplasm of native fish on viability and persistence of native fishes and other aquatic organisms (e.g., amphibia).

4.6 Migratory birds

Objective: Promote high levels of demographic productivity for northern Wisconsin's native bird populations, particularly species which are declining elsewhere in their ranges or whose ranges are centered in the Great Lakes region.

Background: Global declines in neotropical migrant birds have been the subject of considerable attention during the past decade (Hagen and Johnston 1992). Future destruction or modification of wintering habitats is inevitable, making high levels of reproduction in northern breeding grounds critical for population stability. Species such as

Broad-winged Hawk, Black-billed Cuckoo, Least Flycatcher, Veery, Golden-winged Warbler, Nashville Warbler, Black-and-white Warbler, Blackburnian Warbler, Chestnut-sided Warbler, Black-throated Green Warbler, Mourning Warbler, Ovenbird, Rose-breasted Grosbeak, and Scarlet Tanager are quite common today in northern Wisconsin, yet their regional populations may depend on overproduction in forest landscapes like northern Wisconsin and the Upper Peninsula of Michigan.

Populations of forest birds and other long-lived vertebrates might persist in degraded forest environments for many years despite a steady (or even irregular) decline towards extinction. If 99 young are produced for every 100 deaths, for example, a songbird population of several hundred thousand individuals might persist for centuries. The decline itself might be difficult to recognize but nevertheless inexorable. Metapopulation dynamics on a regional scale might further complicate and undermine the survival of these species.

Recommendation: Identify and protect "production areas" for species such as Blackburnian Warbler, Golden-winged Warbler, Scarlet Tanager, and others. These areas should encompass large blocks or complexes of optimal breeding habitat. Information from existing surveys can be used to initiate efforts.

Research Needs: Much remains to be learned about the habitat needs of northern Wisconsin's avifauna. Although information is accumulating about population distributions and even regional abundances, the productivity of local populations must be assessed in order to identify key areas. Continued monitoring is important for recognizing long-term declines before critically low numbers are reached.

4.7 Isolation sensitive species

Background: Due to their rarity and low vagility, several species in northern Wisconsin are vulnerable to the deleterious effects of small population size. Spruce Grouse, Sharp-tailed Grouse, and Boreal Chickadee, for example, are non-migratory and restricted to localized areas of special habitat (open barrens in the case of the Sharp-tailed Grouse, lowland forests and bogs in the case of the other two). Other lesser-known species or localized and isolated habitats (e.g., Northern Blue Butterfly) likely share the same qualities.

Inbreeding, loss of genetic variability, and local catastrophes are potential problems for these isolation sensitive populations because immigration from other areas fails to compensate stochastic events.

Recommendations: The most straightforward recommendation for isolation-sensitive species is to identify where local populations occur. Once identified, the small populations need to be monitored regularly to signal local declines or increases. On the long-term, consideration of habitat corridors and translocations are most appropriate for these isolation-sensitive species.

Research Needs: Although this recommendation derives from information about bird species, their general mobility and predominantly migratory habits mean that few of

northern Wisconsin's birds can be considered isolation sensitive. Species of other taxonomic groups (e.g., small mammals, soil invertebrates, herbaceous plants, etc.) are much more likely to be isolation-sensitive and need to be given the considerations described above.

4.8 Large carnivores and other mammals

Objective: Restore viable populations of large carnivores and other large mammals to the northern Lake States.

Background: Because of its regional scope, this objective may require National Forests to serve as core areas for source populations (regional metapopulations). The most immediate target species are wolf, lynx, and moose. Suitable habitat for large carnivores includes an adequate prey base, sufficient connectivity at landscape and regional scales (i.e., no major barriers such as cities, intensive agriculture, or major highways), and protection from human persecution. Contiguous forest and low road density are important landscape (and habitat) requirements for large carnivores. Road density and associated human access have been found to be good indicators of wolf habitat suitability. Separate studies in northern Wisconsin (Thiel 1985), northern Minnesota (Mech et al. 1988), and northern Michigan and southern Ontario (Jensen et al. 1986) have demonstrated that landscapes with road densities exceeding 0.9 mi./sq. mi. of roads equivalent to Forest Service traffic service levels A, B, and C (USDA Forest Service 1986) generally do not maintain wolf populations. Exceptions have been documented only in landscapes adjacent to large roadless areas (Mech 1989). Wolverines, lynx, and to a lesser extent, black bear and cougar, probably have similar dependencies on remoteness for maintaining viable populations. Restoration of moose requires reducing deer densities and maintaining a larger landscape patch structure in suitable areas.

Recommendations: All recommendations will require close cooperation with the Wisconsin DNR and other land management agencies. Where feasible and where the objective is to provide for these key large carnivores, reduce average open road density to less than 0.9 mi./sq. mi. and maintain buffer areas with road densities lower than is currently found on the National Forests. Road closures can be phased in over time to reduce social impacts. Cooperate with other landowners to assure connectivity between potential core areas or source populations in the Michigan's Upper Peninsula, northern Wisconsin, and northern Minnesota. Linkages between core areas should have low road density, but not necessarily as low as the core areas. Identify priorities for road closures (both temporary and/or permanent).

Research Needs: Obtain road density estimates for each Forest as a whole, by ecological units within the Forests, and for the surrounding and intervening regional landscape. Obtain data on wolf population densities and movement patterns throughout region. Investigate options for wolf population enhancement as well as for reintroduction of other carnivores and large-body mammals.

4.9 Exotic species

Objectives: Reduce risks from exotic species in the Forests. Avoid practices that introduce or encourage establishment of exotics.

Background: Following disturbance, many introduced species are capable of replacing native species. Such shifts in species composition may reduce population and community resiliency or disrupt ecological processes. Many exotic species are introduced inadvertently. Other species escape from sites of intentional introduction. For example, exotic grasses and forbs used for stabilization of roads are routinely introduced into the National Forests. Many exotics spread to undisturbed communities as a result of disturbance in adjacent or near-by communities. It is important that pest/exotic species management programs be designed that are sensitive to other biodiversity management strategies.

Exotics are a major threat to native diversity (3.A.1 in Table 3.1). Exotics often displace native species due to aggressive colonization and rapid growth when introduced to new locations. In many cases, the life histories of exotic invaders or the significance of their impacts is not yet understood sufficiently to suggest specific management recommendations. However, it should be a general management goal on the Forests to reduce the impacts of exotic species.

Recommendations:

(1) Discontinue the use of exotic species in revegetation programs on the Forests and limit the use of nonlocal seed sources. This measure is needed to minimize the erosion of genetic variation within species adapted to local conditions, and help maintain the ecological diversity of native plant and animal communities.

(2) Identify and propagate several species of native graminoids (grasses, sedges, rushes) and forbs suitable for road right-of-way plantings under various conditions, in order to minimize the deliberate spread of exotics through the Forests. Develop alternative seeding mixes for revegetation programs using native species. Sources of species that can be readily grown and harvested in sufficient quantity to support forest needs should be developed.

(3) Develop an interagency outreach plan to educate the public regarding problems associated with exotic species introductions. Development in and around the Forests is a major source of exotic species. Educational materials should be developed to provide examples and explanations of how exotics can threaten the natural biodiversity of the Forests. Homeowners and landscapers need to be educated regarding use of native species for landscaping.

(4) Restoring healthy ecosystems provides the best control of exotics. Invasion of exotics is often symptomatic of degraded natural communities.

(5) Avoid disturbances to the Forests that encourage exotic invasion, such as use of

excessively wide fire lanes and road right-of-ways, and large landing and decking areas.

(6) Fish stocking and wildlife reintroductions should use native germ plasm.

(7) Limit wildlife introductions until impact of species in question is thoroughly examined (e.g., elk reintroduction in northern Wisconsin).

Research Needs: Researchers need to identify native species that can provide quick initial site stabilization and long-term cover. Investigate control measures for exotic species compatible with natural ecological processes.

4.10 Vertical structure

Objective: Increase structural diversity by creating multi-layered stands.

Background: Extensive harvesting in the Great Lakes region has created vast even-aged stands with little vertical structure. Young, even-aged forests typically have little vertical structure until they approach maturity and gaps open up the canopy, allowing regeneration and growth to occur in the gaps. Gap formation can be accelerated using normal silvicultural practices such as group selection, or modified basal area marking guides. A multi-layered vertical canopy favors a multitude of species, thereby enhancing diversity.

Recommendations: Create gaps in a manner that encourages regeneration and growth of ground flora, shrubs, and subcanopy trees. Maintain a mix of even- and uneven-aged stands on the landscape using a variety of silvicultural practices such as clearcutting, shelterwood, and single-tree and group selection.

Research Needs: More research is required on whether artificial gaps in maturing stands simulate old-growth gaps in developing vertical structure.

4.11 Horizontal patchiness (canopy gaps)

Objective: Maintain or restore canopy gap patterns and other aspects of horizontal patchiness that are typical of mature and uneven-aged forests.

Background: Forest harvesting has replaced mature and naturally disturbed forests with young even-aged forests over large areas. Old forests are usually more heterogeneous in horizontal pattern than young managed forests, with higher rates of gap formation, larger gaps, tip-up mounds and pits, and other structural features.

Structural homogeneity can result in losses of biological diversity. For example, canopy gaps may be important for maintaining a variety of ground flora and subcanopy species, particularly within northern mesic communities. Canopy gaps may not be abundant or well distributed in managed stands because trees seldom reach the decay stage necessary for small-scale gap formation, or silvicultural treatments maintain uniform tree canopies.

Recommendations:

(1) Experiment with methods to accelerate attainment of horizontal heterogeneity in young, even-aged forests through single tree or group selection harvesting.

(2) Lengthen rotation age in some management units or cover types to increase probability of natural gap formation.

(3) Simulate gap dynamics by appropriate silvicultural techniques. Augment gaps where pockets of advanced regeneration of midtolerant species are threatened by premature closing of the canopy.

Research Needs: Quantify horizontal pattern of older forests. Document growth rates, flowering and fruiting, demographic parameters of woody and herbaceous plants in gaps versus closed canopy understory. Test various experimental treatments for enhancing horizontal patchiness in younger stands. Study the response of understory species (including spring ephemerals) to a variety of canopy openings. Determine how well various silvicultural systems simulate some aspects of horizontal patchiness found in mature forests. Determine optimal size and orientation of gaps to favor different tree species. Study gap size and distribution (e.g., group selection vs. single tree selection) relative to possible fragmentation and edge effects.

4.12 Microhabitats

Objective: Promote sustainable populations for species at microhabitat scales.

Background: Key features of reproductive biology for plants, many invertebrates, and microorganisms are related to the distribution of individuals at the microhabitat scale. Sustaining their populations involves maintaining spatially dependent life-history phenomena such as breeding, social interactions, and defense against other species. This configuration is influenced by many factors including the distribution of resources (canopy openings, food, nest sites, soil conditions, etc.) and interactions with other species. Forest management can both disrupt or enhance these factors either directly or indirectly by modifying microhabitats and the distribution of species. Pollinators are more effective in facilitating plant reproduction, for example, if the plants occur in close proximity to one another. Fruit dispersal and other mutualisms probably follow the same general rule. Disease and herbivory are likely to spread much more quickly among closely spaced plants or animals than they would among more widely spaced plants or animals. Predators are more likely to affect prey in a given area if the prey are concentrated.

Forest management activities that alter microhabitat conditions inevitably result in a redistribution of individuals within a population. The long-term persistence of resident species might be modified positively or negatively by some change in the distribution of resources such as food, shelter, or habitable space. Small mammals, invertebrates, microorganisms, and non-woody plants with poor dispersal capabilities are most likely to be affected.

Recommendations: The best configuration of resources and populations is likely one that approximates the dynamic context in which species have evolved. Those forest management activities that lead to novel microhabitat structure should be minimized, modified, or sparingly applied as long as the ecological and evolutionary dynamic balance within the overall landscape is maintained. Examples of undesirable practices include: the regular (even) spacing of seedlings during reforestation; eliminating snags, coarse woody debris, and other potential mitigating structures; and the obliteration of underground runways, root structures, and other microhabitat features that are important for small organisms. Positive steps can be taken by maintaining some areas with little or no disturbance of ground structure, prohibiting mechanical harvesting in sensitive areas, and exploring creative ways to configure mitigation structures like fallen logs and stumps.

Research Needs: Very little is known about the significance of population structure at the microhabitat scale. Research on selected species or species groups like ants, ground beetles, reptiles, and amphibians should be encouraged.

4.13 Ground flora

Objective: Mitigate the effects of harvesting on ground flora diversity.

Background: Northern forests often have a high diversity of vascular plants in their understories. Ground flora not only provides diversity itself, but provides habitat and food for other vertebrates and invertebrates, and may influence tree seedling establishment. The impact of harvesting on ground flora depends on the intensity and frequency of the disturbance. Metzger and Schultz (1984) found the long term impacts of selection harvesting on ground flora in northern hardwood stands to be minimal. Following total-tree harvesting in a mixed maple-oak forest, recovery was dominated by forest species with extensive underground stems (rhizomes), while other ground flora species common to the preharvest forest declined in abundance following harvest (Crow et al. 1991). The application of herbicide as part of this study caused an abrupt change from forest species to early successional species (including many exotic weeds) in the ground flora.

The extreme rarity of some understory species (e.g., Calypso Orchid, Hooker's Orchid, Round-Leaved Orchid, Adder's Tongue Orchid, Goblin Fern, Braun's Holly Fern) puts them at risk from harvesting activities. Other understory species with limited dispersal (e.g., herbs with ant-dispersed seeds) are also at risk.

Recommendations: Good design of logging operations is critical to minimizing impacts on ground flora. Surveys for sensitive plants prior to logging are essential. To minimize impacts on the ground flora, schedule logging operatings during the winter whenever possible.

Research Needs: Although some research exists for common ground flora species, more research is needed on impacts of harvesting on rare species, and on commercially important species such as club mosses. More information is needed about flora/fauna relations, and on the role of ground flora in ecosystem processes.

4.14 Below ground (soil)

Objective: Minimize the impacts of forestry operations on the forest floor and mineral soil.

Background: Soil and climate are controlling factors for biological diversity. Harvesting treatments such as clearcutting expose the forest floor and soil surface to solar radiation, causing soil warming, increased surface evaporation, increased nutrient leaching and oxidation of the litter organic layer. This can have a dramatic, though often temporary, effect on organisms populating the forest floor and the surface several inches of the soil. Impacts often lessen once the regenerated canopy begins to close.

Recommendations:

(1) Disturbance to the forest floor and A and B soil horizons should be minimized in harvest operations to reduce soil compaction, erosion, or water flow impedance. This is especially critical with the increased use of large equipment in forest harvest operations.

(2) When clearcutting, scarification, or fire are applied as management tools, minimize the time that the site is exposed before vegetation is re-established. Harvesting which minimizes forest floor disturbance and retains microhabitat structure within stands will allow faster recovery of forest floor and soil organisms and ecosystem functions.

(3) Winter logging generally reduces the destructive impacts of heavy equipment on the forest floor and mineral soil.

(4) Retain patches of various sizes within harvest areas where the understory and forest floor are not disturbed.

Research Needs: Very little is known about the impacts of management on soil microorganisms, and subsequently stand productivity and diversity. A starting point is to determine the impacts of various management treatments on invertebrate and fungal populations in the soil and to better understand the importance of these organisms relative to long-term site productivity.

4.15 Coarse woody debris

Objective: Maintain or restore levels of coarse woody debris (CWD) in managed forests that are typical of mature and old-growth forests.

Background: CWD includes snags and down logs. CWD provides structural diversity that is important both in terms of ecological processes and wildlife habitat. Dead, dying, and down logs and woody debris provide critical habitat for a variety of vertebrates, many invertebrates and fungi. It also provides microsites for seed germination and seedling establishment for yellow birch, hemlock, and other tree species. CWD is associated with many important ecosystem processes such as water and nutrient retention. Intensive and

frequent utilization of woody biomass may result in declines in site productivity. Thresholds for amounts of CWD required to provide habitat and other ecological functions are unknown.

Recommendations:

(1) Where appropriate, use uneven-aged management, or shelterwood systems to retain structural diversity. If clearcutting is used, make specific provisions for retention of current and future CWD. In both even- and uneven-aged management, retain large live trees for recruitment as future snags and down logs. Consider creating CWD with experimental treatments.

(2) Increase the number of residual trees beyond that currently recommended as den and snag trees in the standards and guidelines (Franklin 1992).

(3) Leave some potential salvage sales unharvested.

Research Needs: Determine the relationships between the type, volume, and distribution of CWD, water and nutrient retention, and animal, plant, bacterial, and fungal populations. Determine how to create CWD through various treatments that simulate natural mortality.

4.16 Tip-ups

Objectives: Maintain structural complexity and spatial heterogeneity on the forest floor.

Background: Tip-ups are created by blowdowns of living trees. Habitats that are especially susceptible to windthrow (shallow to bedrock, water table, or hard pan) can experience extensive soil mixing and mounding. These microsites create unique niches that increase structural and compositional diversity. Tip-ups are a common stand structural component in many northern hardwood-hemlock, lowland conifer forests, and older white pine forests. Young, even-aged forests are less likely to have these structural features.

Recommendations: No information exists on how to create tip-ups other than mechanically pulling down the trees. Creating old-growth and uneven-aged forests will eventually restore this process to many stands.

Research Needs: Research does exist on the importance of these micro-sites (e.g., Beatty and Stone 1986). More research is needed to define their role in ecosystem processes. Methods for creating a tip-up should also be explored. The most cost effective manner may prove to be secondary effects resulting from the creation of gaps in the otherwise uniform canopy in second growth. Also, operational studies can be performed during harvests by mechanically pulling down (and leaving) trees of various sizes with skidders. Biological value and cost effectiveness should be evaluated.

4.17 Hydrology

Objective: Minimize the disruption of natural hydrology, including flooding regimes, watertables, and impoundments.

Background: Water movement in and through an ecosystem has far reaching implications for plant growth and landscape pattern. Changes in water levels and water flows (e.g., changes in bog hydrology due to an improperly constructed road) may disrupt ecosystem processes and place associated species at risk. Altered wetlands and aquatic communities are more susceptible to invasion by exotics, such as purple loosestrife and reed canary grass. Species such as these, in turn, severely impact native species. Loss of biological diversity may be associated with stream channel modifications and management strategies that focus on single species (e.g., trout production).

Recommendations:

(1) Vary buffer width as necessary to protect surface water resources from management activities. Because soils, slopes, and acreage of each timber harvest are variable, the protection required and offered by buffers varies. Buffers need to be designed to reduce hydraulic pulsing from storms and to minimize impacts on water quality.

(2) Carefully review all future impoundments and stream modifications to ensure that this work is justified and ecologically sound.

(3) Develop education programs for engineers to give them a better understanding of the impacts of construction activities on the hydrologic properties of ecosystems. Identify projects with quality engineering that are ecologically sensitive as demonstration areas.

Research Needs: More information is needed regarding benefits and tradeoffs of stream and surface water modifications. We do know that beaver are a keystone species that create and maintain essential habitat for many wetland species, but may destroy habitat for some upland species.

4.18 Aquatic and wetland ecosystems

Objectives: Provide quality examples of all aquatic and wetland ecosystems within the boundaries of the National Forests.

Background: Aquatic and wetland ecosystems (lakes, streams, bogs, lowland forests, marshes, sedge meadows, and small spring ponds) are prominent features of the northern Wisconsin landscape. These areas act as coarse filters for the conservation of species; at the same time, their presence can provide other benefits such as prime recreational opportunities and maintenance of water quality. At the landscape scale, the structural and functional characteristics of aquatic and wetland ecosystems are closely related to adjacent terrestrial ecosystems.

We recognize three key structural features of aquatic ecosystems at the landscape level: (1) large-scale hydrology, including groundwater flows and surface drainage; (2) continuity

of stream networks; (3) sediment/nutrient flux from surrounding terrestrial ecosystems. Many of the structural characteristics have been modified by human activities. No major stream system runs without interruption by road culverts, dams, or watercourse modification of some kind. Cabin/resort development dominate the shorelines of all but a few major lakes within northern Wisconsin. If done improperly, road building and repair can lead to sedimentation and interrupted stream flow. Likewise removing tree and brush buffers along streams can create widely fluctuating stream temperatures. Construction of artificial impoundments obviously changes the character of streams (e.g., flow rates, temperatures, chemical properties), but the impacts are not necessarily negative in a broader context.

Recommendations:

(1) Benchmark examples of aquatic ecosystems should be designated and managed to minimize as many of the risks described above as possible. Specifically, at least two examples of first or second order streams and their surrounding watersheds should be managed to avoid stream modification and other major disturbances. Low intensity forestry practices might be acceptable if impacts on the stream are minimized. Likewise, two or more examples of major lake types, bogs, sedge meadows, woodland ponds, and perhaps other aquatic ecosystems should be designated along with their adjacent watersheds. Fishing with live bait and access by motorized boats should be prohibited in these areas to minimize the risks of exotic species introduction and water pollution.

(2) A ½-mile river corridor (¼-mile on each side of the river) is required for Wild and Scenic Rivers. For major rivers within the Forests, this width should be considered necessary to protect ecologically sensitive attributes such as watershed protection and biological migration. A wider corridor may be necessary in some cases to provide adequate protection to aquatic and riparian features. For small streams, buffers should be variable along stream sides depending on the type of stream, surrounding topography, and contiguous vegetative cover so as to provide natural shading and filtering of lateral water movement.

(3) Harvesting done on other forest lands adjacent to wetlands should be conducted in an ecologically sensitive manner so as to minimize impacts to adjacent wetlands.

4.19 Roads

Objectives: Better recognize the impacts of roads on land use patterns and on ecological processes. Reduce road densities within some areas of the National Forests in Wisconsin.

Background: Roads are essential for many management activities, but they also profoundly affect land use patterns and ecological processes. For example, roads can alter the topography, interrupt air and water drainage and water movement, and if improperly constructed or improperly used, can drastically increase rates of erosion and siltation. Road orientation, width, and surfaces influence local microclimates. Roads can significantly alter hydrologic flows and thus alter landscape patterns.

High road densities are characteristic of human-dominated (cultural) landscapes. Few roadless areas or even areas with low road densities exist in northern Wisconsin.

Recommendations:

(1) Road construction should consider water drainage, especially over somewhat poorly drained soils and wetlands. Adequate culverts or other techniques to permit near "free-to-flow" water movement should be built into plans.

(2) Each National Forest should have a roadless area along with areas in which maintaining low road densities is a primary management objective.

(3) Carefully review chemicals used in road maintenance and determine their potential impacts, especially in wetlands and aquatic communities. Use only those compatible with the systems in which they are applied. The Nicolet and Chequamegon National Forests should work with other local and state government agencies to minimize the use of road de-icing and dust controlling chemicals in the Forests. Many organisms are very sensitive to salts and related chemicals (carriers, flowability agents, dyes, etc.).

Research Needs: Additional research is needed on the relation of the road network and land use patterns. Some research has been conducted relating road density to the movement and survival of wide-ranging mammals such as the timber wolf, but additional research is needed on the effects of roads on the movement of a wider array of organisms. Little is known about the effects of roads on forest fragmentation in a northern forest landscape. More research is needed on the impacts of cut and fill on water movement down slopes and on sheet water movement, as well as subsurface flows in wetlands.

4.20 Dispersal barriers

Objective: Identify and, to the extent feasible, minimize artificial barriers to movement and dispersal of native plants and animals.

Background: In terrestrial systems, landscape features such as urban development, major highways and their right-of-ways, and agricultural fields can be barriers to the movement of some species. Conversely, corridors such as roads and right-of-ways can also promote the dispersal of species such as exotics and other pests. In aquatic systems, dams represent an significant barrier to the movement of species.

Artificial movement barriers, added to natural barriers such as rivers, lakes, and disturbed areas, may significantly impede movement of many terrestrial species. Movement barriers are particularly problematic for wide-ranging mammals with low population densities, and for animal species that hesitate to cross openings or disturbed areas. However, until we understand the types of barriers and their relation to other factors, e.g., climate change, the risks are difficult to determine.

Recommendations:

(1) Close or gate roads that are not essential to the implementation of the Forest Plan.

(2) Build roads only to standards required to implement specific activities outlined in the Plan while being sensitive to the influence that roads can have on animal movement.

(3) Maintain low road densities within some areas of the Forest to provide remoteness.

(4) Allow canopies along roads to close (i.e., "crown-over") to lessen the impact of roads as barriers to movement of some species.

Research Needs: Empirical information is needed about the value of corridors for a variety of species. Likewise, landscape features that act as barriers to the movement of animals (and related dispersal of plants) need to be better identified for forested areas such as northern Wisconsin.

4.21 Innovative silvicultural techniques

Objective: To restore and/or mimic natural (historic) disturbance regimes and landscape processes within the northern forest.

Background: Silvicultural practices have traditionally been applied to control composition of tree species, diameter distribution (i.e., the stand structure) , and stand stocking with the goal of maximizing production of wood. Innovative silvicultural practices should also be applied with the complementary goal of conserving biological diversity.

Recommendations:

Dry forests

(1) Use prescribed burning (perhaps in combination with harvesting to reduce fuel loads) to restore a canopy structure and understory composition more reflective of communities in which fire was an important aspect of the historic disturbance regime. On the driest and least fertile sites, jack pine barrens and red pine forests burned frequently, were severely degraded by fire suppression, and are in the greatest need of prescribed burns today. On somewhat moister or more fertile sites, less frequent fires may be needed to help generate stands dominated by white pine, paper birch, and red oak. On the most mesic sites, fire at even less frequent intervals (or on fewer sites) might be needed to foster reproduction by yellow birch and hemlock.

(2) Manage pine plantations to maintain greater diversity in composition and structure. Goals include a more open canopy (with a greater diversity of tree sizes and species, at least in red pine stands), natural tree regeneration, and adequate light to support shade-intolerant herbs and shrubs characteristic of jack and red pine stands. Management of established plantations might include thinning substantial fractions of the canopy at long intervals, or prescribed burning. In addition, new plantations might be planted at lower densities, with admixtures of other canopy species.

Mesic forests

(3) Use selection cutting to mimic natural gap dynamics in mixed hardwood stands. Goals are to favor more trees of intermediate shade tolerance to generate mixed age- and size-structures for trees, and to increase canopy and understory diversity. We recommend an Arbogast-like technique, modified to incorporate variation in gap size (through occasional aggregation of plots harvested per entry on a site), allow sugar maple, yellow birch, hemlock, and white pine to reach tree ages of 200-300 years in some managed stands, and do not harvest all large culls likely to die naturally before the next entry. Variation in gap size may be especially important in favoring different tree or understory species.

(4) Reintroduce hemlock, yellow birch, and white pine to some stands. Due to extensive harvesting and subsequent fires at the turn of the century, abundance of these species in many second-growth forests has declined. If mimicking gap dynamics is to be successful, local seed sources for these tree species must be available. Human intervention may be the only method for reintroducing these species over large areas in a reasonable period of time (although deer browsing may confound such attempts, and require direct efforts to reduce deer density). Unpublished data (M. Davis, pers. comm.) suggests that, at least at low densities, hemlock may play an important role in northern mesic forests, fostering higher diversity in the herb layer.

(5) Consider clearcutting and fire as possible techniques for re-establish even-aged hardwood/hemlock/white pine stands. Underburning may be required to reduce the dominance of sugar maple in the advanced regeneration of some stands, and thereby encourage white pine, hemlock, basswood, and yellow birch.

(6) Don't discriminate against non-commercial tree species during logging. Often, non-commercial species such as ironwood are automatically removed during harvest, unnecessarily reducing biological diversity. In some cases, such non-commercial species should be retained.

(7) Use longer rotations (and a greater variety of rotations) for even-aged management on mesic sites. For uneven-aged management of northern hardwoods, allow trees to grow into large diameter classes (>20 inches dbh).

(8) Minimize disturbance to associated herbs, shrubs, and saplings during tree harvest, by adjusting the seasonal timing and the extraction techniques used in logging (see 4.13).

(9) Reduce the area committed to short-rotation aspen, and reduce its interdigitation into areas of mixed hardwoods. The current commitment threatens to reduce beta and gamma diversity, and its extensive spatial distribution is a contributing factor to excessive deer densities. Additional techniques for maintaining short-rotation aspen (e.g., 2-entry systems, aspen-fir culture) should be explored as a means of ecologically diversifying an extensive forest type within the Nicolet and Chequamegon Forests. Where aspen culture is the primary management objective, use larger clearcuts, but with more complex shapes, and retain 5-15% of the stems across the size classes to

maintain structural complexity and CWD through next rotation.

(10) At least part of the area taken from short-rotation aspen should be allowed to succeed naturally for another 50 to 100 years, to increase landscape-level seral diversity. In general, attempts should be made to have examples of each kind of even-aged stand (jack pine, aspen, hardwoods/hemlock/white pine) go through a full successional sequence.

Wet forests

(11) Conservation of biological diversity should be considered the leading value in managing northern white cedar swamps. These communities are a major "hot spot" for rare plant species (including several orchids of short stature), are of limited spatial extent, and their regeneration is poorly understood; consequently, their conservation should be a high priority.

(12) Research is needed on the potential use of fire to manage spruce-larch swamps. An important role of fire in maintaining these swamps is suggested by the serotinous habit of black spruce; we need to know how fire might influence the structure and composition of such communities, perhaps by resetting succession through peat ignition and water-level alteration.

4.22 Climate change

Objective: Develop strategies for dealing with the effects of climate change on the natural ecosystems of the Chequamegon and Nicolet Forests.

Background: Plants and animals are very sensitive to climate. Each species has a different climatic tolerance that depends on life history characteristics, species mobility, rates and magnitudes of climatic change. It is the view of many climatologists that a doubling of preindustrial CO_2 concentrations along with other greenhouse gases in the atmosphere will cause a warming of $3° \pm 1.5°$ C (WMO 1982, NRC 1983). These changes are projected to occur within the next 50 to 100 years. If this occurs, the projected rate of warming will be extremely rapid compared with historic change. Even a 1° C change in this time frame could have a large effect on ecological systems.

While there is a great deal of uncertainty related to projected climatic change, many climatologists assign a high probability to warming for several reasons. First, the importance of atmospheric composition on climate is well known as are the processes that create the greenhouse effect. Second, the climatic models used to predict future conditions do a reasonable job of predicting both present-day seasonal changes and past paleoclimates (Webb 1992). Third, the global mean temperature has increased 0.5° C during the past century (Jones and Wigley 1990). While it is impossible to tell if this warming is due to greenhouse effect, the trend is in the expected direction.

Understanding the potential impacts of global warming on natural ecosystems is

complicated. Among the projections are large shifts in the ranges of species, some shifting hundreds of kilometers north of their present range, causing vegetative communities to break up and to reform with new species associations. For example, Davis and Zabinski (1992) project that in response to 3° C of global warming, sugar maple, beech, yellow birch, and hemlock will shift hundreds of kilometers or more northward. Davis and Zabinski also note that many understory species will be more susceptible to warming than the dominant overstory species.

Many ecological processes could be dramatically changed by global warming. For example, decreased soil moisture and warmer temperatures may enhance the chance of fire, increase fire intensity, and allow a larger area to be burned by increasing the forest fuel levels. Also, the probability of insect outbreaks may change due to altered density of predators or parasites (which react to climate change), a change in availability of host species, or changes in their own life history characteristics in response to increased temperature. Processes such as nutrient mineralization and organic matter decomposition could be affected (Pastor and Mladenoff 1992). On loamy soils, warmer temperatures may allow greater decomposition rates and increased growth rates for tree species. In contrast, on sandy soils decreased soil moisture can result in a shift to species with lower growth rates, less biomass, and poor litter quality. The existing mosaic of soil conditions will result in a new distribution of forest communities. The new landscape pattern will have ramifications for the plants and animals dependent on those forest systems.

While many members of the Roundtable viewed potential climate change as a major threat to biological diversity (5.A in Table 3.1), developing practical recommendations to minimize the effects of climate change was difficult and problematic. All perceived regional and global threats to biological diversity in Table 3.1 were ranked as low in amenability to change from management because of the limited ability of managers on the Nicolet and Chequamegon National Forests to modify or mitigate large-scale problems. Recommendations:

(1) Because of the uncertainty associated with regional climate change, resource managers need to take a risk-management approach. This is a proactive approach in which contingency plans are developed for a range of possible climatic conditions. Forest managers and planners need to anticipate the possibility that significant climatic change could occur within the rotation length of most tree species. Whether or not the projected warming occurs, climatic change has always occurred, and resource management decisions should be based on the assumption that environmental conditions are dynamic, not static.

(2) Managers and planners also need to be reactive to global warming with management decisions based on information obtained from forest monitoring. Changes in the following processes or components should be monitored on the Forests: nutrient cycling, soil moisture content, tree growth rates, stream flows, lake and wetland levels, selected animal populations, insect and disease outbreaks, community composition, species ranges, and reproductive success..

(3) Ecosystems and species that are likely to be especially sensitive to global warming

should be identified and appropriate conservation strategies developed.

Research Needs: Increased emphasis in the Forest Service's Northern Global Change Research Program is needed at the landscape and regional scales. Field research should be directed to studies along altitudinal and latitudinal ecotones. Baseline information to determine long-term trends is critical and thus institutional support is needed for long-term ecological research.

4.23 Inter- and intra-agency coordination and cooperation among ownerships

Objective: To improve the management of biological diversity through inter- and intra-agency cooperation and outreach to other land managers in the region.

Background: Within the East, federal lands account for a small portion of the total landscape. Ownership patterns are fragmented and interdigitated. Federal lands in Wisconsin can contribute to regional biological diversity, but alone they are inadequate to maintain and enhance regional biological diversity. Cross authority between agencies does exist for managing some resources (e.g., wildlife management), but no formal mechanism currently exists for coordination among ownerships for managing biological diversity. In some cases, agreements with neighboring landowners such as state, county, and tribal lands can be helpful in coordinating management goals. Coordinated monitoring and data sharing among agencies is essential.

Although global and regional effects on biological diversity may originate outside the jurisdiction of the Forest Service, impacts may significantly affect the Forests. These effects must be monitored and considered when developing long-range plans for managing biological diversity in the Forests.

Recommendations:

(1) Increased levels of coordination within the Forest Service among Research, NFS, and State and Private Forestry is recommended in the areas of monitoring, inventory, management, and research in order to implement an adaptive management strategy.

(2) The National Forests in Wisconsin should explore the concept of a biosphere reserve or a similar designation as a coordination mechanism at the regional level. Use the Southern Appalachian Biosphere Reserve as a model.

(3) The Forest Service should take a leadership role in coordinating among ownerships and assessing regional biological diversity.

(4) The Environmental Roundtable is comprised of federal agencies in the Midwest. It should be expanded to include nonfederal agencies and organizations representing private ownerships and could be used as the primary body for regional coordination.

(5) We encourage data sharing, common data collection, developing common standards for

data acquisition, storage, and retrieval among agencies.

(6) Complete the Ecological Classification and Inventory System (EC&I) at the province, section, and subsection levels of the hierarchy as well as those levels supporting project planning at the Forest and Opportunity Area levels (landtype association, ecological landtype, and landtype phase).

(7) Apply a landscape perspective to resource management, e.g., better understand the broad ecological context in which the Nicolet and Chequamegon National Forests exist during the next round of forest planning.

Chapter 5

RESEARCH AND MONITORING NEEDS

5.1 Research and monitoring play critical roles in forest management.

Throughout Chapter 4, we followed most management recommendations with a statement regarding what further monitoring or research is needed to pin down the extent of risk or how that threatened element of diversity might respond to changes in management. Research needs were also flagged in Table 3.1 corresponding to incomplete or fragmentary scientific knowledge. Some of the threats to diversity identified in the Table have not yet been studied enough to assess their severity or significance (e.g., the impact of repeated logging on terrestrial nutrient cycling - item 3.B.1.b). Even in cases where scientists suspect a potentially significant threat, their level of scientific confidence in the extent or pervasiveness of the impact may remain limited. For example, we don't yet know how the loss of natural individual tree gap dynamics across a region might threaten the persistence of particular herbaceous plant and invertebrate species (1.B.2. in Table 3.1). In other instances, we both recognize a threat and have scientific confidence that the threat is real and substantial, but do not yet know how effectively some alternative forest management approach might ameliorate the threat. An example would be the degree to which edge-sensitive bird species are responding to roads and timber harvests in northern Wisconsin (Howe et al. 1993).

In all these cases, the Roundtable scientists recognized the need for additional research. The Roundtable also agreed on the need to monitor the effects of ongoing forest management on particular elements of diversity, both to catch unanticipated declines and to gauge the extent to which management may encourage the recovery of sensitive elements. While members of the Roundtable have considerable experience, their research has not always been conducted in the upper Great Lakes region nor has their research always address the questions of most relevance to this region (e.g., forest fragmentation research done in isolated woodlots of the lower Midwest).

To address these needs more specifically, one special Sub-group worked one afternoon to discuss and highlight particular issues and needs in the area of biological inventories, monitoring, and research. It was the general feeling of the group that efforts in these areas need to be expanded and more closely integrated with each other and with routine forest management (as did the Interagency Spotted Owl Scientific Committee - Murphy and Noon 1991). Implementing the recommendations of the Roundtable will require that the Forests couple certain changes in management with further research and monitoring. While some such changes are based on solid scientific ground and previous results, others address suspected or potential threats to diversity and are necessarily more experimental.

The Forests should move rapidly to facilitate the further research and monitoring needed to address the issues identified in this Report. However, we recognize that research remains a slow and often intensive process and that monitoring efforts may require many years before clear trends can be detected. We also acknowledge the fact that completing

the research called for in Chapters 3 and 4 is unlikely, given traditional levels of funding. We therefore seek in this chapter to target specific research questions and monitoring needs that we feel deserve special or more immediate support. Such efforts obviously should be coordinated amongst themselves so as to focus on those issues of greatest concern. They should also be re-evaluated periodically to ensure their relevance and to guide changes in management when these are warranted.

The Forest Service has been criticized for not following the inventory and monitoring requirements laid down in NFMA, for not following through with monitoring programs outlined in the forest plans, and for generating sparse, poor quality, inconsistent, and out-dated information (Office of Technology Assessment 1992). Some of these deficiencies stem from funding priorities and staffing levels that have more to do with Congressional appropriations than policy choices by the Forest Service. While the Roundtable was in no position to judge the sources of these inadequacies, we urge National Forest administrators and the members of Congress's Agricultural and Appropriations Committees that oversee the Forest Service to acknowledge the need to adequately fund research and monitoring efforts capable of providing the accurate and up-to-date information needed by today's forest managers.

Who should do the research and monitoring recommended in this Report? The Roundtable scientists all felt that research, monitoring, and forest management should be more closely integrated (see recommendation 4. in section 5.2 below). Yet this has proved difficult, perhaps in part to the traditional separation of research from management within the Forest Service. While this division is essential to maintain the independence and thus the credibility of the research branch, Roundtable members were generally in favor of closer cooperation and coordination between the Forest Service research and National Forest System management on the two Forests. More specific recommendations in this regard are beyond the scope of our deliberations.

In some instances, it may also prove possible to fund further research or monitoring efforts using outside sources, such as local colleges and universities or the "Partners" programs the Forests have established with certain private groups (e.g., The Nature Conservancy, the Ruffed Grouse Society, etc.). We hope, by drawing attention to specific research needs in this document, to aid the Forests in encouraging appropriate and targeted research among outside researchers. It is important, however, that such research complement, rather than drive, research and monitoring efforts on the two Forests. It is also unrealistic to expect such groups to sustain comprehensive research programs consistently over many years.

While further research and monitoring will help to resolve points of uncertainty, it would be inappropriate to use the need for more research to delay or avoid making changes in management likely to benefit threatened elements of diversity. Both science and forest management advance by using the most complete and accurate knowledge available at any given time to guide their activities.

5.2 Principles to guide research and monitoring efforts.

How can scientists ensure that public resources expended for research and monitoring bring the greatest possible returns? While the brevity of the Roundtable prohibited making detailed recommendations or designing detailed programs, our discussions did generate several ideas that should contribute to future research and monitoring efforts on the Forests. We state these here in the form of principles that we feel should guide the design of detailed research and monitoring programs:

1. **Research and monitoring should emphasize those elements of diversity thought either to be most vulnerable to extirpation and sensitive to human-made disturbances or to be "keystone" species likely to have cascading effects on other elements of diversity.**

   Resources are too few to allow comprehensive monitoring of all elements of diversity. Rather than tracking ubiquitous or common species, research and monitoring efforts should emphasize those species and communities known or suspected to be in decline. Special efforts should be dedicated to track species or habitat elements of conservation concern and species or elements known to be vulnerable to widespread anthropogenic disturbance. It also may be important to track particular common or increasing species if these species play a crucial ecological role and so influence community composition or the ability of rarer or more threatened elements of diversity to persist (see below).

2. **Research and monitoring efforts should employ the best available scientific knowledge and methodology (quality control).**

   The Wisconsin Forests should build on Forest Service experience and the lead provided by this Roundtable by constructing a "state-of-the-art" research and monitoring effort addressing biodiversity concerns. By investing limited resources wisely, the Forests have the opportunity to provide a concrete and constructive example of how to design and implement approaches to assessing and conserving biodiversity.

   Given the size, importance, and mandate of the National Forests to conserve diversity, the Roundtable considers it essential for the Forest Service to ensure that their limited research and monitoring resources be used in the most efficient and effective way. To accomplish this, the Forests should employ skilled and knowledgeable technical personnel with adequate training in contemporary principles of ecology, population biology, and conservation biology. Where such personnel are in short supply, the Forests should consider re-training other existing qualified staff and/or contracting out particular projects.

   There is also a need for regular and periodic review of research and monitoring efforts both within and outside the agency, regardless of whether these efforts derive from Forest staff or independent parties. Other agencies (e.g., the Geological Survey) routinely apply peer review both to approve research proposals and to evaluate their results and interpretation. The Forest Service should also apply formal peer review for

the design, establishment, and revision of their research and monitoring programs (as they already do for the publication of research results). We recognize that the Roundtable itself represents a substantial step in the direction of obtaining expert outside opinion. We urge the Forests and the Research arm of the Forest Service to sustain this momentum by regularly seeking independent external review of their research and monitoring programs.

3. **The Forests should provide a general response to the recommendations contained in this Report to the Roundtable participants sometime over the next 6-12 months.**

   While a response to each recommendation made by the Roundtable is not necessary, a general description of how the recommendations are being implemented on the Forests is appropriate. Some recommendations have already been implemented on the Forests. For other recommendations, staff specialists will need to develop more specific guidelines depending on local conditions. And in some cases, the recommendations may not be viewed as appropriate or feasible. Thus, it would be valuable for Roundtable participants to receive some indication of the perceived value of their recommendations.

4. **The results of research projects and monitoring efforts should be closely integrated with forest management.**

   Both research and monitoring provide information essential to forest managers if they are to base their management decisions on a full awareness of probable environmental effects. Research and monitoring efforts therefore need to be "built in" to ensure that accurate, up-to-date information is available at appropriate points in planning and management cycles. Clear channels and procedures are needed to regularly and reliably inject this information into management.

   Ad hoc arrangements between forest planners, managers, forest ecologists, wildlife resource specialists and researchers may not consistently provide opportunities to integrate research and monitoring results with specific projects. Such integration should clearly also occur on the appropriate scale -- attempts to address diversity concerns stand by stand or even opportunity area by opportunity area are inferior to a system that ties decisions at each level to diversity concerns at that level.

   There is also a need to ensure that management responds to new data on an ongoing basis, changing continuously with the continual flow of new information. The continuing rapid advance of ecological and conservation science suggests that approaches considered state-of-the-art today may become inappropriate or inadequate as conditions and opportunities change in the future. Thus, we urge both Forests to vigorously pursue policies of "adaptive management" in which planning efforts and management decisions evolve in tandem with growing scientific understanding of the consequences of those decisions.

   In addition to management benefiting from information resulting from research and

monitoring, research and monitoring can themselves benefit by being more closely integrated with management. Each management decision provides, in effect, an opportunity to pursue research into the consequences of that decision, provided adequate planning and controls are established in advance. Management provides opportunities for researchers to embark on larger-scale and more ambitious research projects than are possible only via research funds. Several of the research needs noted here and in Chapter 4 could take immediate advantage of the different patterns of cutting and other forest manipulations if these routine management activities were integrated into a carefully conceived research design that included appropriate controls and documentation. Such research and monitoring is particularly important in efforts by the Forests to restore particular habitat types, given our primitive knowledge base in restoration ecology. Efforts should therefore be taken to ensure that adequate funding is available to integrate research and monitoring with management.

5.3 Inventory and monitoring efforts should be expanded and systematized.

Both Forests depend on biological inventory and monitoring to assess how well diversity is being maintained and how management practices are affecting particular elements of diversity. These efforts provide the primary base of biological information for the Forests, making it essential that the information be as accurate and up-to-date as possible. As with research, the complexity of the many elements of biological diversity make inventory and monitoring a daunting task and needs far outstrip available resources. Because it is impossible to track all, or even a substantial fraction of, relevant components, structures, and processes, the Forests must rely on monitoring a subset of ecological indicators. Clearly, these indicators should be carefully chosen and the methods used to track them should be carefully worked out to provide reliable information in the most efficient and timely way possible. Such efforts should also be coordinated between the two Forests and across the region to provide maximum sensitivity and economy.

Some excellent inventory and monitoring programs have been established on the Chequamegon and Nicolet National Forests. These include the annual Nicolet National Forest bird survey, the survey of herps conducted on the Eagle River District of the Nicolet National Forest to determine which species populate wood land ponds and surrounding upland areas, and the rare plant species inventory being conducted on the Chequamegon National Forest. These programs deserve continued and expanded support on the Forests.

In this section, we provide a set of specific recommendations regarding inventory and monitoring efforts. The next section provides a similar set of recommended research efforts. It should not be construed, however, that these are independent. Routine monitoring will provide opportunities to economize on research, provided these monitoring efforts are designed with specific goals in mind. Similarly, further research may identify additional elements of diversity that should be incorporated into monitoring schemes, or indicate that some current element is a poor or inappropriate indicator. Thus, research and monitoring will naturally coevolve and should be considered integral parts of "adaptive management."

1. **Inventory and monitoring efforts should be expanded and systematized to place them on the best scientific footing and ensure a continual yield of high-quality and timely information.**

   At present, the Forests only have comprehensive data on species occurrence for a portion of the vertebrate animal species community. More species are monitored, including some rare and sensitive plant species, but these efforts should be reassessed and perhaps redesigned in accord with the recommendations below to make them as informative and efficient as possible. This redesign will obviously need to take fiscal constraints into account.

2. **Monitoring should occur across a hierarchy of geographical scales.**

   Rather than conducting inventory and monitoring efforts on a species by species approach, the Forests should adopt a hierarchical approach that will include the systematic gathering and interpretation of data across several geographical scales, as outlined and recommended by Noss (1990). At the highest landscape scale, such efforts might include data on forest types, openings, surrounding land uses, the distribution of potential corridors, and measures of habitat area and the degree of fragmentation. Many of these data for the Nicolet may already exist in its MOSS data base and could perhaps be extended and integrated across the region using data from aerial or satellite surveys (see 3. below). At the community level, the Forests, in cooperation with Forest Service Research, should assemble consistent information on cover type from the evolving Ecological Classification and Inventory System (EC&I) and explore and test the utility of these data for biological monitoring and planning. Data at the species level from regular monitoring efforts could then be integrated into these higher geographical levels to provide better understanding of how management is likely to affect edge-, area-, and isolation-sensitive species.

3. **The Forests should extend their ecosystem classification and mapping to include several levels within the hierarchy and should standardize the classification system between the two Forests and with other National Forests within the region.**

   In conjunction with the hierarchical approach to monitoring, the Forests need to continue developing and applying current approaches to ecosystem classification and inventory (EC&I) adopted by the Eastern Region (multi-scale, hierarchical, integrated multi-factor classification). These classifications provide the basis for assessing biological diversity at many different spatial scales. The EC&I system should also be extended to include aquatic, wetland and open-land community types. EC&I also provides a useful basis for collecting and organizing geographical information.

4. **The Forests should promote landscape planning efforts.**

   Once assembled, these geographic data should be systematically examined (presumably using Geographic Information System technology) to assess which community types are least well represented and protected. In addition to evaluating the value of existing reserved lands (wilderness, research natural areas, state natural areas, parks, etc.), this

effort should also assess the extent to which surrounding state, county, and private lands act to enhance or reduce the persistence of threatened elements of diversity present within the Forests. Those community types deemed to be under-represented or threatened by fragmentation and isolation should then become a priority for subsequent research, monitoring and appropriate management efforts. Ideally, these efforts would be integrated into a regional "gap analysis." While these approaches represent in many ways the cutting edge of conservation biology, they require a great volume of high quality data, pointing up the need for more accurate and complete inventories and continued monitoring.

5. **Inventory and monitoring efforts should be extended to include other important but obscure groups of organisms.**

   In both Forest Plans, most biological inventory and monitoring efforts are placed on a few specially chosen indicator species. While it is tempting to continue monitoring those visible groups of plants and animals that we already know a good deal about, there may be several advantages to evaluate other groups of organisms for their indicator and monitoring potential. To ensure that some critical elements of diversity are not being overlooked, additional efforts should be made to inventory and monitor alternative taxonomic groups. Amphibians, for example, are known to be ecologically sensitive to habitat conditions and are experiencing declines in many areas around the world. Other relatively obscure groups are known to be functionally important (e.g., bacteria, lichens, and fungi for their role in N-fixation and nutrient cycling). Certain lichen species associated with old-growth forests elsewhere have also been found on old-growth trees in the Chequamegon Forest and trees of various ages in the Nicolet. We need to assess the extent to which such species are restricted to older trunks and forest types. Although soil fungi play critical ecological roles as diseases, mycorrhizae symbionts, and decomposers, many species are undergoing substantial declines in Europe for unknown reasons. Some monitoring effort should therefore be allocated to these in northern Wisconsin.

   Invertebrates represent the most diverse group on the Forests and are functionally important as well, both as pest species on trees (e.g., the spruce budworm and woolly adelgid) and as biological control agents (the many parasite and parasitoid species). Their generally short life cycles make them potentially good ecological indicators in that their population levels will respond quickly to changes in environmental conditions. Studies of old-growth forests in the Pacific Northwest suggest high levels of herbivorous insects in young stands, but greater densities and diversities of predaceous and parasitic invertebrates in old-growth stands. Such patterns should be investigated in the Forests for at least some arthropod groups (e.g., some beetle group and/or moths). many are relatively easy to sample, but their identification would require collaboration with experts in the field. Butterflies are easy for amateurs to identify, however, and also include species known to be both rare or threatened and sensitive to ecological function (e.g., the Karner Blue Butterfly and its dependence on fire-generated habitat for its food plant, lupine). While such efforts would probably be experimental at first, one or more of these groups might eventually become a mainstay of routine monitoring efforts.

6. **Inventory and monitoring efforts should include entire guilds or communities in cases where such sampling is efficient.**

In many instances, it will be more efficient to sample most or all of a plant or animal community rather than a few individual species or processes. Once methods are developed to sample individuals, it may represent comparatively little additional work to obtain information on a set of species composing a guild. In other cases, monitoring might be extended to include most species in the community. For example, songbird populations are routinely assessed by song surveys that involve listening for set periods of time at a series of evenly spaced sampled points. A qualified birder can almost as easily record all the bird species heard at a point as one or a few species using little additional time.

Once obtained, data from full guilds or communities will allow the Forests to track more elements and processes than single species, providing more statistical power to detect systematic changes (i.e., changes in ratios of abundances or other composite indexes can be used rather than tracking a single time series). Inventory and monitoring efforts should take advantage of such economies of scale whenever possible.

7. **Invading species exotic to the area should be monitored to assess their rates and avenues of spread and impacts on other elements of diversity.**

Invading exotic species (e.g., Purple Loosestrife, Garlic Mustard, Spotted Knapweed, Gypsy Moth and Zebra Mussel) represent both a direct threat to many natural communities and, in many cases, sensitive indicators of anthropogenic disturbance. Invading exotic plant species typically thrive in open, disturbed habitats and frequently disperse along roadsides or attached to boats or vehicles. Both Forests should therefore monitor the distribution, abundance, and rates of invasion by exotics, as well as the effects of roads, disturbance, and fragmentation on their spread. Eradication may also be needed where there is evidence that such invasions threaten elements of diversity (Temple 1990).

While rare and declining elements of diversity represent a natural focus of concern for conservation biologists, their intrinsic scarcity both makes them difficult to track efficiently and limits sample sizes, compromising our ability to notice or assess declines statistically. To avoid these difficulties, Forest managers may find it expedient and informative to track the distribution and abundance of certain invading species. Such species often provide an efficient indicator of anthropogenic disturbance. The same shift in disturbance regimes or other environmental conditions that may threaten species sensitive to anthropogenic disturbance often benefits those species adapted to quickly colonize disturbed sites. It will frequently be easier to train personnel to track common, abundant species, and these data will provide ample sample sizes for statistical significance. To work well, this approach should be coupled with other research and monitoring efforts to calibrate the degree to which increases in these indicators correspond to decreases in sensitive species.

8. **Where possible, use demographic structure or other "early warning signs" to assess changed ecological conditions rather than simple population numbers.**

   It has been customary to monitor populations by their size or density, using declines in abundance to trigger more intensive conservation efforts. This approach may provide too little data too late for long-lived species where adults may persist long after conditions have become untenable for their offspring. In addition, it will often be statistically difficult to demonstrate declines for rare species with limited sample sizes (e.g., breeding bird surveys - Terborgh 1989). To provide earlier warning and better statistical power, resource managers should consider monitoring demographic variables such as reproductive success and size or age structure in populations of species that are long-lived or otherwise of special concern. In addition to providing earlier and more sensitive indicators of imminent population decline, such variables can also often provide insights into the mechanisms driving these population losses. While these methods are often more labor intensive, the data they produce are often of much greater value than simple trends in population size.

5.4 Particular needs for further research

To complement the recommendations for further research contained in Table 3.1 and Chapter 4, we recommend specific research to answer the following questions:

1. **What rates of loss, fragmentation and/or degradation are occurring for particular habitat types?**

   Maintaining adequate areas of each distinct habitat type would immediately protect many of the components, structures and functions of those habitats and so serve as an efficient "coarse filter" in a comprehensive and hierarchical approach to conserving biodiversity. Of course, a top down approach of this kind requires high quality input data, hence our recommendations 2. and 3. in section 5.3 above regarding the necessity for comprehensive and consistent community classifications based on up-to-date information. This recommendation also parallels our call for a regional gap analysis.

2. **What are the ecological effects of multiple, short-rotation tree cutting? Do such effects threaten ecological or economic sustainability?**

   The Plans call for parts of both Forests to be managed intensively with short-rotation aspen or plantation pine. Surrounding commercial timber lands are also managed using intensive cutting schedules. In addition, proposals to alleviate cutting pressures on some areas could intensify cutting on other lands in order to meet timber outputs. Thus, the Forests, in conjunction with the North Central Forest Experiment Station and the Region, should expand their research into the short- and long-term ecological impacts of short-rotation harvests. Here, we are particularly concerned that short-rotation harvests, especially those based on whole-tree harvesting, may deplete soil nutrients (e.g., nitrogen and phosphorus) or otherwise interfere with normal nutrient availability and cycling and so impair long-term productivity. There is also some evidence to suggest that short-rotation harvests of aspen may exacerbate infestations of

the fungal pathogen *Armillaria* (Stanosz and Patton 1987). Either or both of these effects may seriously compromise the ability of the Forests to maintain their timber outputs and so represent a clear research priority. They also reflect how interference in historical disturbance regimes may cause major and difficult-to-reverse changes in key ecological processes.

3. **What are the ecological effects of edge habitats on the biota of northern Wisconsin?**

   Edge habitats are increasingly widespread in human-dominated landscapes and are thought to threaten several components of diversity by boosting densities of keystone herbivores, small opportunistic predators, and nest parasites. Edges may also serve as corridors to boost the invasion of exotics (see recommendation 7. in 5.3 above). Nevertheless, some controversy remains as to the degree to which these processes operate in primarily forested landscapes. To resolve these points of uncertainty and to assess the severity and scale of these effects, the Forest Service should support research on the degree to which roads, clearcuts, and other natural and human-caused disturbances affect various elements of diversity. For example, we do not yet know the degree to which neotropical migrant birds in the region may suffer increased rates of nest predation by raccoons or blue jays or nest parasitism by the brown-headed cowbird, or the degree to which these opportunistic predators and parasites use roads or edges to search for prey. Poaching of game and non-game species may also occur most frequently near trails or roads. Although these are obvious examples, there may also be more subtle impacts of roads, trails, or other edges on the distributions or abundances of rare and threatened species.

4. **Do the effects of habitat fragmentation interfere with dispersal or recolonization in particular species so as to threaten their populations?**

   Biologists have become increasingly aware of how important meta-population dynamics can be in influencing the ability of populations to persist. Many sub-populations appear to serve as sources for dispersing individuals, while others clearly act as net population "sinks." Species with limited abilities to disperse across barriers (e.g., some birds, many herbaceous plants, salamanders, etc.) are particularly prone to the effects of habitat fragmentation. Other species may be sensitive to habitat area (e.g., if their population dynamics involve repeated dispersal to re-colonize sites after a characteristic disturbance). Both species restricted to forested habitats and species characteristic of open grasslands may experience such effects. Thus, a combined approach should be made to assess the simultaneous effects of forest type, patch size, fragmentation, and edge on the production and persistence of those species sensitive to habitat isolation and fragmentation (e.g., forest interior and grassland bird species).

5. **What are the effects of fragmentation on the spread and local persistence of species and communities arranged along environmental gradients?**

   Many species shift their distribution continuously in response to short- and long-term shifts in environmental conditions. The importance of such shifts may change in the

future if climatic conditions undergo a significant long-term change as many predict. Habitat isolation and fragmentation may become increasingly important in the mid-term as species respond to these changes. While intensive short-term research efforts probably are not justified, comprehensive and consistent long-term monitoring will be essential for tracking these responses.

6. **What ecological processes regulate abundance or opportunities for population recruitment?**

   Concerns for diversity in general and rare species in particular have frequently been limited to identifying a few key species of concern, then monitoring either population levels or presumed habitat needs for those species. As we gain a more dynamic view of populations we recognize that successful recruitment and persistence often depend on disturbance, interactions with herbivores or carnivores, or other key ecological processes. This emphasis on process points up the need for more detailed and dynamic information on population structure and demography, complementing recommendation 8. regarding population monitoring in 5.3 above.

7. **Do remaining old-growth forests contain unique elements or other distinguishing features?**

   Current management decisions are often based on incomplete or inadequate knowledge regarding the structure, composition, and function of old growth communities. Such communities are now scarce in the region and have lost top carnivores and perhaps other elements of their diversity. Nevertheless, they provide an essential control or baseline against which management and restoration efforts aimed at reconstituting old growth can be judged. The Forest Service should support research on the species composition and other unique characteristics of these communities, including: soil composition and dynamics (including mycorrhizal associations and ecological roles of soil invertebrates); relationships of herbaceous species to disturbance and soils; and dispersal characteristics and population dynamics of associated vertebrate (birds, small mammals, bats, and herptiles) and invertebrate species.

8. **To what extent can silvicultural practices or other methods of active management successfully mimic these old-growth characteristics?**

   Given baseline information on the composition and processes of old-growth communities, the Forests next face a need to determine how well the needs of old-growth species are met by active (and passive) methods of forest management. We recommend that research investigate how well techniques of manipulative management can mimic natural processes in old growth stands and so provide the structural and functional features needed by old growth associated species. Such techniques should include artificially produced gaps, efforts to provide coarse woody debris, and perhaps groundfires in appropriate communities.

9. **What is the ecological significance of gap formation?**

Gaps influence a wide variety of species, both directly and indirectly. There is thus the need to assess the effects of various gap sizes and types on components of diversity (primarily understory tree seedlings and herbaceous plants). Such research should include the effects of micro-topography, microclimate, and local light levels on plant growth and recruitment.

10. **What were the original distributions of native species that have been extirpated or reduced in range?**

Several native animals were systematically extirpated (e.g., cougar and woodland caribou) or remain severely reduced in distribution from their original range (e.g., moose and gray wolf). Some conservationists and wildlife enthusiasts have proposed re-establishing such species in part or all of their original ranges, including the National Forests. Aside from other difficulties such re-introduction efforts sustain, they also encounter the difficulty of determining where these animals occurred, what habitat elements their occurrence depended on, and how abundant they were. Further historical or archaeological research would help delineate their requirements and the corresponding suitability of current habitats.

11. **How are high deer densities affecting other elements of diversity?**

Contemporary densities of white-tailed deer have grown at times to levels far higher than those thought to have occurred historically. High densities of deer may have direct or indirect effects on many components of diversity. Evidence from exclosures and the scarcity of seedlings of certain tree species (hemlock, white pine, white cedar, and red oak) suggest that deer could act as a "keystone" herbivore and so drive forests toward a composition of species more tolerant of deer browsing. Lilies, orchids, and other scarce and threatened herbaceous species may also suffer reduction or extirpation. In addition, browsing has been found to influence the composition of bird and mammal communities dependent on understory shrubs or other cover, in studies in other regions. Finally, high deer densities may also act to exclude other ungulates from the region by providing a reservoir of a parasitic worm that infects the brains of elk and moose (or perhaps via competitive effects).

While several on the Roundtable felt strongly that efforts should be taken to reduce deer densities across the region, all Roundtable participants recognized that the ultimate solution to the problem is a political one. Regardless, further information on the regional extent and severity of browsing impacts on the composition and structure of forest ecosystems, and more specific knowledge regarding what densities and distributions of deer cause such effects, would help forest managers to work with wildlife managers to achieve populations of deer compatible with sustained forest diversity and productivity. In addition, deer densities reciprocally respond to vegetation and patterns of logging (primarily aspen and openings for summer forage, logging "tops", and conifer stands for thermal cover in winter). Quantifying these relationships would assist forest managers in understanding how their management decisions influence deer abundance. To address these concerns, the Forest Service should support and encourage current and proposed research to obtain information on

what thresholds exist regarding damaging effects and how local or regional vegetative conditions influence local and regional deer densities.

12. **How do beaver populations respond to vegetative management and how do their populations influence other elements of diversity?**

Beaver, like deer, may act as an ecological "keystone" species by damming streams, with cascading effects for other plant and animal species. While beaver dams typically kill surrounding trees and temporarily reduce stream suitability for some fish species, they also provide habitat for marsh species (e.g., ducks) that may enhance diversity for the region over the long-term. Furthermore, beaver may represent crucial prey for top carnivores like wolves. The Forests should pursue research to ascertain how sensitively beaver population levels respond to surrounding habitat management (e.g., aspen) and how beaver influence other elements of diversity, both locally and regionally.

13. **How does forest unit size affect the current and likely future diversity of an area that is temporarily or permanently isolated?**

To address critical questions regarding the size of reserved habitat areas which may be needed to adequately protect some sensitive elements of diversity, the Forests need further information on species/area curves for representative plant and animal species groups of the different EC&I units. Such research should also ideally involve studies of rates of species loss ("relaxation") and immigration or re-colonization (turnover).

14. **How are over-harvesting, poaching, and harassment of particular wildlife species affecting the distribution or persistence of these species?**

Some once-common species were routinely collected until they became rare (e.g., wild ginseng) or now-common species are being intensively collected (e.g., club mosses). Others may be sensitive to inadvertent human activity (e.g., roads, snowmobile noise, etc.) or actively persecuted by Forest visitors (e.g., poachers intentionally shooting wolves or hunters mistaking wolves for coyotes). Research is needed to assess how human-sensitive wildlife species respond to various degrees of human presence and exploitation. Social science research would also be useful that addresses why some individuals chase, harass, or shoot non-game wildlife, and how such behavior might be modified.

15. **To what degree do rare or threatened elements of diversity depend on dispersal or recolonization via corridors of appropriate habitat?**

Many biologists suspect that habitat corridors play critical roles in the persistence of some area- and disturbance-sensitive species. Unfortunately, few experimental studies and data yet exist on this subject, leaving considerable uncertainty as to which species need, or benefit the most from corridors. It is even conceivable that certain types of corridors might threaten some elements of diversity by increasing edge habitat or providing avenues for the spread of pest species. There is thus a need to investigate

how effectively strips of habitat function as biological corridors, and which species benefit from such "connectedness."

16. **How do disturbance-sensitive elements of diversity respond to various methods of timber harvest?**

Herbaceous plants, reptiles and amphibians (and perhaps other groups) may respond quite differently to different patterns or scales of timber harvest. Research is therefore needed to determine how alternative silvicultural treatments (e.g., differently sized patch cuts, different intervals of harvest, and various practices to leave behind snags and/or live trees) affect their abundance and persistence. Some of these effects may be indirect, as for those many herbaceous plants that depend on animals (e.g., ants or mammals) for dispersal.

Chapter 6

DISCUSSION

6.1 The goals of forestry

With so many factors actually or potentially threatening diversity (Table 3.1), it is not surprising that the Roundtable came up with many management recommendations (Chap. 4). While this diversity of threats and recommendations reflects current understanding regarding the complexity of biological interactions, it also presents problems for those entrusted with translating these concerns into practical management approaches. Which concerns should be given primary attention and priority? Which threats can most easily, and most economically, be countered by relatively simple adjustments to current policies? How can management address all these concerns at once? How soon will additional local research into the effects of specific alternative forest management practices be available to help guide revisions in management policy?

The economic vitality of the communities in northern Wisconsin depends on the wise and efficient utilization of resources from the National Forests. While foresters have traditionally centered their attention on timber, recreation and similar forest outputs, they now face a more complex and difficult task in attempting to effectively implement the recommendations outlined in Chapter 4. A forester's job has never been simple, but managing for complexity is a far different task from managing for the efficient production of one or a few tree species. Furthermore, foresters must now concern themselves with those rare or otherwise threatened elements of diversity that are easily overlooked and might appear unimportant.

Forestry has for much of this century concerned itself with more than cutting trees, and multiple use has been a guiding principle of forest management in the National Forests since at least 1960 and passage of the Multiple Use Sustained Yield Act. Thus, interest for protecting biological diversity fits within traditional concerns for fish, wildlife, water quality, sustained yields, and ecosystem protection. As our understanding of biological elements and processes continues to improve, we will gain a more accurate picture of how forest management affects plant and animal species. This should allow us to design patterns of forest management capable of protecting all native species and the ecological processes they depend on. The recommendations contained in this Report are intended to support management decisions that will sustain both forest resources and the capability of the land to support all species. As foresters continue to pursue multiple use, meshing their concerns for production and protection with the contemporary scientific understanding manifested in this Report, they will face many decisions. Roundtable participants sought to assist forest managers in their complex task by recommending a number of specific management approaches (Chapter 4) and particular avenues of research where the additional knowledge gained will quickly repay its investment (Chapter 5).

In this final chapter, we attempt to aid forest managers further by discussing several issues that provoked particular interest or debate amongst the Roundtable participants or that led to apparent contradictions or conflicts in the recommendations. While discussion

sometimes revealed a particular conflict to be more apparent than real, some inconsistencies remain and represent real trade-offs between alternative biodiversity and/or production goals. Indeed, it would be misleading to assume that all the many threats and goals outlined in this Report could be addressed through any simple, uniform set of management recommendations.

6.2 Significance, uncertainty, and conflicts

Human activities have led to the loss of biological diversity in northern Wisconsin. Whether these activities have been direct, as with clearing the landscape for agriculture, or indirect, as with acid deposition or fire suppression, biological diversity has suffered. The question of whether this loss of biological diversity has or will reduce the sustainability of our National Forests is much less obvious. How should we proceed in the absence of definitive information? Which course of action is the most appropriate when a suspected substantial threat has not yet been proved to the satisfaction of all? The Roundtable wrestled with these questions at many levels.

Most ecologists agree that the loss of biological diversity is both lamentable for its own sake and potentially of great social and economic concern because of the ramifications that may follow. Losing key elements of diversity can directly or indirectly threaten the effectiveness or sustainability of natural ecosystems (although it is usually difficult to predict exactly how or when). Local extirpations represent steps in this process of impoverishment and these losses may be irreversible in cases of extinction. Thus, all losses of biodiversity should be taken seriously. As a general rule, we should do everything reasonable to avoid further exacerbating the problem and make every reasonable effort to restore the diversity already lost.

The lack of full knowledge of the relationships between diversity and sustainability, coupled to the costs associated with maintaining biological diversity, raise many conflicts that are not yet resolved. The most obvious conflict is the desire to fully use the natural resources of the National Forests without knowing how greatly those uses impact biological diversity and sustainability. We have, for example, implemented forest fire control to save timber; we now know that fire (along with wind and perhaps insect epidemics) was a natural process in the forests of northern Wisconsin without which species may be lost. We have cut old-growth forests and favored younger, more rapidly growing forests, reducing those species tied to the unique processes of old growth. We have drained wetlands, constructed roads, converted mixed forests to plantations, and developed most lakeshores, all with the aim of more fully utilizing our natural resources, but with an unknown cost to the diversity of the forests. As we strive to develop management and use practices, we need to devise approaches that will protect the biological diversity of the Forests while still providing access to the natural resources we want. In many instances, the Roundtable scientists felt that additional information was needed to suggest how this could be done. In other instances, the scientists felt enough was already known to dictate specific changes in management or use.

The potential for global warming introduced more uncertainty into our discussions.

Some suggested introducing genes from southern populations to anticipate the need for future adaptation to warmer conditions. Others were quite opposed to this on the grounds that existing patterns of genetic variation need to be protected. In either case, providing more continuous habitats should contribute to the ability of native species to respond adaptively to climatic change.

In addition to these conflicts over uncertainty, forest managers also face potential conflicts in attempting to manage for particular elements of diversity. Forest harvest practices that favor clearcutting and short rotations, for example, also favor beaver and deer. Similarly, hunters generally desire high densities of ruffed grouse and white-tailed deer -- game species favored by clearcutting and short rotations. Yet evidence is growing to suggest that extraordinary deer populations are reducing reproduction in some favored browse species. At the same time, alterations in historical disturbance regimes may be contributing to additional losses in some plant populations. Beaver, as a keystone species, can enhance biodiversity for some species while displacing others. While the Roundtable participants can not prescribe how forest managers should weight these factors in making their decisions, we urge them to anticipate these effects and clump distinct management activities together so as not to homogenize the diversity of forested habitats.

Remarkable consensus emerged on the key threats to diversity and most research and management recommendations. These efforts, however, are only the first step of an ongoing process. Many recommendations state the need for further analysis supported (where possible) by further data. The next steps include a regional gap analysis and an assessment of whether area-, edge-, isolation-, and disturbance-sensitive species in the Wisconsin National Forests warrant the designation of further areas reserved from timber harvesting (see 6.3 below). More refined analyses are needed here to assess minimum area needs, the need for corridors, and the degree to which timber harvesting is compatible with maintaining species sensitive to anthropogenic disturbance. While many felt such recommendations were already supported by existing knowledge, or would be prudent under a situation of uncertainty, others felt that further research is needed before making such decisions.

Some scientists felt that until reserved lands mature, active management is needed to create diverse horizontal and vertical forest structure. Some also argued that creating such structure will require frequent access that requires roads. Others argued that the efficacy of such active forest management efforts for fostering diversity remain unproved and should only be considered experimental. A few also argued that even in the event that active management is deemed necessary, it could be accomplished via hand tools with minimal road access and need not be linked to timber extraction. Most participants agreed that because roads act as dispersal barriers for many plants and animals, and avenues for the dispersal of exotic species, they should be minimized in some areas wihin the Forests.

6.3 Spatial scale and landscape management

The importance of spatial scale for biological diversity has been acknowledged here and elsewhere (e.g., Society of American Foresters 1991). It does not automatically follow,

however, that maximizing species richness at the local level increases or sustains diversity at the regional level. Various elements of diversity operate at various spatial scales. A comprehensive approach to conserving biological diversity includes multiple scales, as reflected in our recommendations.

Perhaps one way out of the conflicts and complexity surrounding efforts to manage for biodiversity is to acknowledge the efficiency of "coarse filter" approaches that protect many elements of diversity at once by segregating competing uses among management areas. Some areas aimed principally at conserving diversity could simultaneously address many of the recommendations presented in Chapter 4. In such areas, managers would seek to restore natural rhythms and frequencies of disturbance across areas large enough to sustain viable populations of many edge-, area-, isolation-, and disturbance-sensitive species. The establishment of such areas would relieve pressures to sustain viable populations elsewhere in stands more intensively managed for timber production or motorized recreation.

Thus, uncertainties remain as forest managers face the complex tasks of adjusting management policies to encompass broader concerns for biodiversity. Scientists within the Forest Service and their cooperators stand ready to assist the Forests in completing the more extensive analyses required to determine appropriate sizes for areas intended to provide habitat for disturbance-sensitive and forest interior species. Social scientists should simultaneously explore the social and economic consequences of clumping management activities into larger blocks and intensifying timber management in some areas to relieve economic pressures to harvest timber from areas that provide key habitat for threatened elements of diversity. At the same time, the Forest Service should develop their working relationships with a broader set of public and private groups to enhance their ability to communicate their broad set of goals and the need for cooperation.

6.4 The need for vision and leadership

Viewing diversity from a broad spatial scale demonstrates the importance of regional planning that coordinates land management across resource management agencies and ownerships. With the exception of fire control, little formal coordination exists among public resource management agencies, and even less between public and private ownerships. Our tradition of English common law confers considerable property rights to private landowners, rights that are jealously guarded by those who sometimes feel threatened by proposed coordination of land management activities across ownerships. However, many landowners in northern Wisconsin manage their lands primarily for recreation and aesthetics -- goals that are not necessarily detrimental to sustaining regional biodiversity.

While it is unrealistic to expect instant or full coordination, it is important that some governmental body fill the vacuum that now exists by assuming leadership to foster the development of a coordinated regional approach to conserving biodiversity. Because no other agency or organization has the same opportunity or expertise, it is logical that the Forest Service take this leadership role. We urge the Forest Supervisors in the Lake States and the Regional Forester to explore possible mechanisms for increasing coordination and

cooperation among public agencies and between public and private ownerships. Many Roundtable participants offered to assist the Forest Service in their efforts to develop a practical, comprehensive and scientifically-based plan capable of perpetuating regional diversity and the amenity values the public expects from its public forests.

The Roundtable succeeded in bringing science to bear on the complex and difficult issues surrounding biodiversity. Preparatory work provided by the staffs of the Forests combined with the expertise present, helped crystallize the issues, and precipitated many constructive and concrete suggestions regarding forest management. We make these research and management recommendations with the hope that they will provide useful tools for managers intent on achieving a more comprehensive and rigorous approach to ecosystem management.

REFERENCES CITED

Apfelbaum, S. and A. Haney. 1991. Management of degraded oak savanna remnants in the Upper Midwest: Preliminary results from three years of study, p. 81-89. In: J. Ebinger, Ed. Proceedings of Oak Management Workshop, Bradley University, Peoria, IL.

Beatty, S.W. and E.L. Stone. 1986. The variety of soil microsites created by tree falls. Can. J. For. Res. 16: 539-548.

Cooley, J. L., and J. H. Cooley (eds.). 1984. Natural diversity in forest ecosystems. Workshop Proceedings, Institute of Ecology, U. of Georgia, Athens, Ga. 290 p.

Crow, T.R. 1989. Biological diversity and silvicultural systems, p. 180-185. In: Proceedings of the National Silvicultural Workshop, Petersburg, Alaska. Forest Service, Timber Management, Washington, D.C.

Crow, T.R., G.D. Mroz, and M.R. Gale. 1991. Regrowth and nutrient accumulation following whole-tree harvesting of a maple-oak forest. Can. J. For. Res. 21: 1305-1315.

Council on Environmental Quality. 1993. Incorporating biodiversity considerations into environmental impact analysis under the National Environmental Policy Act. CEQ, Washington, D.C. 29 p.

Davis, M.B. and C. Zabinski. 1992. Changes in geographical range resulting from greenhouse warming: effects on biodiversity in forests, p. 297-308. In: (R.L. Peters and T.E. Lovejoy, eds.) Global Warming and Biological Diversity, Yale University Press, New Haven.

Franklin, J.F. 1988. Structural and functional diversity in temperate forests, p. 166-175. In: Biodiversity, (ed., E.O. Wilson). National Academy Press, Washington, D.C.

Franklin, J.F. 1992. Scientific basis for new perspectives in forests and streams, p. 25-72. In: New perspectives in watershed management. Springer-Verlag, New York.

Frelich. L.E. and C.G. Lorimer. 1991. Natural disturbance regimes in hemlock-hardwood forests of the upper Great Lakes region. Ecol. Monograph 61: 145-164.

Hagan, J.M., III, and D.W. Johnston (eds.). 1992. Ecology and conservation of neotropical migrant landbirds. Smithsonian Institution Press, Washington, D.C. 609 p.

Haney, A. and S.I. Apfelbaum. 1993. Oak barrens of the upper midwest. Castanea (in press).

Harris, L.D. 1984. The fragmented forest. University of Chicago Press, Chicago, IL. 211 p.

Hobbs, R.J. 1992. The role of corridors in conservation: Solution or bandwagon?

TREE 7: 389-392.

Howe, R.W., S.A. Temple, et al. 1993. Forest management and birds in northern Wisconsin. Passenger Pigeon 54: 297-305.

Hunter, M.L., Jr. 1990. Wildlife, Forests, and Forestry: Principles of managing forests for biological diversity. Prentice Hall, Englewood Cliffs, NJ. 370 p.

Jensen, W.F., T.K. Fuller, and W.L. Robinson. 1986. Wolf (Canis lupus) distribution on the Ontario-Michigan border near Sault Ste. Marie. Can. Field-Nat. 100: 363-366.

Jones, P.D. and T.M.L. Wigley. 1990. Global warming trends. Sci. Am. 263: 84.

Mech, L.D. 1989. Wolf population survival in an area of high road density. Am. Midl. Nat. 121: 387-389.

Mech, L.D., S.H. Fritts, G.L. Radde, and W.J. Paul. 1988. Wolf distribution and road density in Minnesota. Wildl. Soc. Bull 16: 85-87.

Metzger, F. and J. Schultz. 1984. Understory response to 50 years of management of a northern hardwood forest in upper Michigan. Am. Midl. Nat. 112: 209-223.

Mladenoff, D.J. and J. Pastor. 1993. Sustainable forest ecosystems in the northern hardwood and conifer region: concepts and management. In: Defining Sustainable Forestry, (eds., G.H. Aplet, J.T. Olson, N. Johnson, and V.A. Sample). Island Press, Washington, D.C.

Mladenoff, D.J., M.A. White, J. Pastor, and T.R. Crow. 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecological Applications 3: 294-306.

Mooney, H.A. and M. Godron (eds.). 1983. Disturbance and ecosystems, components of response. Springer-Verlog, New York. 292 p.

Murphy, D.D. and B.D. Noon. 1991. Coping with uncertainty in wildlife biology. J. Wildlife Management 55: 773-782.

Noss, R. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Cons. Biol. 4: 355-364.

NRC (National Research Council). 1983. Changing Climate. Washington, D.C. National Academy Press.

Office of Technology Assessment. 1987. Technologies to maintain biological diversity. Summary. Government Printing Office, Washington, D.C., Stock No. 052-003-01058-5.

Office of Technology Assessment. 1992. Forest Service Planning: Accommodating uses,

producing outputs, and sustaining ecosystems. Government Printing Office, Washington, D.C., Stock No. 052-003-01264-2.

Pastor, J. and D.J. Mladenoff. 1992. The southern boreal - northern hardwood forest border, pp. 216-240. In: (H.H. Shugart, R. Leemans, and G.B. Bonan, eds.) A Systems Analysis of the Global Boreal Forest. Cambridge U. Press, New York.

Pastor, J. and W.M. Post. 1988. Response of northern forests to CO2-induced climate change. Nature 334: 55-58.

Probst, J.R. and T.R. Crow. 1991. Integrating biological diversity and resource management. J. For. 89: 12-17.

Reader, R.J. and B.D. Bricker. 1992. Value of selectively cut deciduous forest for understory herb conservation: an experimental assessment. Forest Ecology and Manage. 51: 317-327.

Reid, W.V., and K. R. Miller. 1989. Keeping options alive: the scientific basis for conserving biodiversity. World Resources Institute, Washington, D.C. 128 p.

Runkle, J.R. 1985. Disturbance regimes in temperate forests. In: The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York.

Scott, J.M., B.Csuti, et al. 1991. Gap analysis: assessing protection needs, p. 15-26. In: Landscape Linkages and Biodiversity. Washington, D.C., Island Press.

Society of American Foresters. 1991. Biological diversity in forest ecosystems. Bethesda, MD 52 p.

Soule, M., ed. 1985. Conservation biology: The science of scarcity and diversity. Sinauer Associates, Sunderland, MA. 584 p.

Stanosz, G.R., and R.F. Patton. 1987. Armillaria root rot in aspen stands after repeated short rotations. Can. J. For. Res. 17: 1001-1005.

Temple, S. 1990. The nasty necessity: eradicating exotics. Cons. Biol. 4: 115-117.

Terborgh, J. 1989. Where have all the birds gone? Princeton, NJ, Princeton University Press. 207 p.

The Keystone Center. 1991. Biological diversity on federal lands. Keystone, CO. 96 p.

Thiel, R.P. 1985. The relationship between road densities and wolf habitat suitability in Wisconsin. Am. Midl. Nat. 113: 404-407.

Turner, M.G. (ed.) 1987. Landscape heterogeneity and disturbance. Springer-Verlag, New York. 239 p.

USDA Forest Service. 1986. National forest roads for all uses. Eastern Region, Milwaukee, WI. 19 p.

Webb, T., III. 1992. Past changes in vegetation and climate: lessons for the future, p. 59-75. In: (R.L. Peters and T.E. Lovejoy, eds.) Global warming and biological diversity. Yale University Press, New Haven.

Wilson, E.O. 1988. The current state of biological diversity, p. 3-18. In: (E.O. Wilson and F.M. Peter, eds.) Biodiversity. National Academy Press, Washington, D.C.

Wilson, E.O. and F.M. Peter (eds.) 1988. Biodiversity. National Academy Press, Washington, D.C. 521 p.

WMO (World Meteorological Organization). 1982. Report of the JSC/CAS: A Meeting of Experts on Detection of Possible Climate Change. Report WCP29. Geneva: World Meteorological Organization.

Appendix A

ROUNDTABLE PARTICIPANTS

Mr. Steve Apfelbaum
Applied Ecological Services
P.O. Box 256, Route 3, Smith Road
Brodhead, Wisconsin 53520

Dr. Robert Brander
National Park Service
Apostle Islands National Lakeshore
Route 1, Box 4
Bayfield, Wisconsin 54814

Dr. Robert L. Burgess
SUNY College
Environmental and Forest Biology
Syracuse, New York 13210

Dr. Michael S. Coffman
Environmental Perspectives
1229 Broadway, Suite 313
Bangor, Maine 04401

Dr. Thomas R. Crow
USDA Forest Service
North Central Forest Experiment Station
Forestry Sciences Lab
P.O. Box 898
Rhinelander, Wisconsin 54501

Dr. Virginia H. Dale
P.O. Box 2008
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6038

Dr. Margaret B. Davis
Ecology, Evolution & Behavior
University of Minnesota
1987 Upper Buford Circle
St. Paul, Minnesota 55108

Mr. Eric Epstein
Wisconsin Department of Natural Resources
Bureau of Endangered Resources
Madison, Wisconsin 53707

Dr. Thomas Frost
Trout Lake Station
Boulder Junction, Wisconsin 54512

Dr. Tom Givnish
University of Wisconsin-Madison
430 Lincoln
Madison, Wisconsin 53706

Dr. Alan Haney
College of Natural Resources
University of Wisconsin-Stevens Point
Stevens Point, Wisconsin 54481

Dr. John Kotar
University of Wisconsin-Madison
Department of Forestry
Madison, Wisconsin 53706

Mr. Jim Meeker
Great Lakes Indian Fish & Wildlife Commission
P.O. Box 9
Odanah, Wisconsin 54861

Dr. Constance Millar
USDA Forest Service
Pacific Southwest Forest and Range Experiment Station
P.O. Box 245
Berkeley, California 94701-0245

Dr. David J. Mladenoff
University of Minnesota-Duluth
Natural Resources Research Institute
Duluth, Minnesota 55811

Mr. Mike Mossman
Wisconsin Department of Natural Resources
1350 Femrite Drive
Monona, Wisconsin 53716

Dr. Reed Noss
Conservation Biology
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon 97331

Dr. Forest W. Stearns
3040 Sorenson Road
Rhinelander, Wisconsin 54501

Dr. Jim Sweeney
American Forest and Paper Association
1250 Connecticut Avenue NW, Suite 200
Washington, D.C. 20036

Dr. Stanley Temple
University of Wisconsin-Madison
333 West Mifflin Street, Suite 107
Madison, Wisconsin 53703

Dr. Donald M. Waller
Department of Botany
University of Wisconsin
430 Lincoln Dr.
Madison, WI 53706

Dr. Robert Howe
UW-Green Bay
2420 Nicolet Drive
Green Bay, WI 54311-7001

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